VOLUME II of II, PAGE APPX3131-8559

2018-1766, -1767

United States Court of Appeals for the Federal Circuit

TQ DELTA, LLC,

Appellant,

– v. –

CISCO SYSTEMS, INC., DISH NETWORK LLC, COMCAST CABLE COMMUNICATIONS, LLC, COX COMMUNICATIONS, INC., TIME WARNER CABLE ENTERPRISES LLC, VERIZON SERVICES CORP., ARRIS GROUP, INC.,

Appellees.

Appeals from the United States Patent and Trademark Office, Patent Trial and Appeal Board in Nos. IPR2016-01020, IPR2016-01021, IPR2017-00254, IPR2017-00255, IPR2017-00417, and IPR2017-00418.

JOINT APPENDIX

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v.
CISCO SYSTEMS, INC., et. al., Petitioners/Appellees

APPEAL NO. 18-1766, 18-1767

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7.8 Gain scaling

Each point (X_i, Y_i) or complex number, $Z_i = X_i + jY_i$, output from the encoder is multiplied by the fine gain adjuster, g_i:

$$Z_i' = g_i Z_i$$

The g_i define a scaling of the rms sub-carrier levels relative to those used in R-MEDLEY (see 12.7.8). They are independent of any methods that manufacturers may use to simplify implementation (e.g., constellation nesting).

7.9 Modulation

The frequency spacing, Δf, between sub-carriers shall be 4.3125 kHz with a tolerance of + 50 ppm.

7.9.1 Sub-carriers

7.9.1.1 Data sub-carriers

The channel analysis signal, defined in 11.5.2, allows for a maximum of 31 carriers (at frequencies $n\Delta f$, n=1 to 31) to be used. The lower limit on n is determined by the ADSL-POTS splitting filters; if FDM is used to separate the upstream and downstream signals, the upper limit on n is set by the down-up splitting filters. The cut-off frequencies of these filters are completely at the discretion of the manufacturer because in either case the range of usable n is determined during the channel estimation.

7.9.1.2 Pilot

Carrier #16 (f = 69.0 kHz) shall be reserved for a pilot; that is $b_{16} = 0$ and $g_{16} = 1$. The data modulated onto the pilot sub-carrier shall be a constant {0,0}. Use of this pilot allows resolution in a receiver of sample timing modulo-8 samples. Therefore a gross timing error that is an integer multiple of 8 samples, could still persist after a micro-interruption (e.g., a temporary short-circuit, open circuit or severe line hit); correction of these is made possible by the use of the synchronization symbol defined in 7.7.4.

7.9.1.3 Nyquist frequency

The carrier at the Nyquist frequency (#32) shall not be used for data; other possible uses are for further study.

7.9.2 Modulation by the inverse discrete fourier transform

The modulating transform defines the relationship between the 64 real values x_k and the Z_i'

$$x_k = \sum_{i=0}^{63} \exp(j\pi\, ki/32)\, Z_i'$$

The encoder and scaler generate only 31 complex values of Z_i' (plus zero at dc and one real value if the Nyquist frequency is used). In order to generate real values of x_k these values shall be augmented so that the vector Z' has Hermitian symmetry. That is,

$$Z_i' = \mathrm{conj}\,[Z_{64-i}'] \qquad \text{for } i = 33 \text{ to } 63$$

7.9.3 Synchronization symbol

The synchronization symbol permits recovery of the frame boundary after micro-interruptions that might otherwise force retraining.

The symbol rate, f_{symb} = 4 kHz, the sub-carrier separation, Δf = 4.3125 kHz, and the IDFT size, N = 64, are such that a cyclic prefix of 5 samples could be used. That is,

$$(64 + 5) \times 4.0 = 64 \times 4.3125 = 276$$

The cyclic prefix, however, is shortened to 4 samples, and a synchronization symbol (with a nominal length of 68 samples) is inserted after every 68 data symbols. That is,

$$(64 + 4) \times 69 = (64 + 5) \times 68$$

The data pattern used in the synchronization symbol is the pseudo-random sequence PRU (d_n, for n = 1 to 64), defined by

$$\begin{aligned} d_n &= 1 && \text{for } n = 1 \text{ to } 6 \\ d_n &= d_{n-5} \approx d_{n-6} && \text{for } n = 7 \text{ to } 64 \end{aligned}$$

The bits shall be used as follows: the first pair of bits (d_1 and d_2) is used for the dc and Nyquist sub-carriers (the power assigned to them is, of course, zero, so the bits are effectively ignored); then the first and second bits of subsequent pairs are used to define the X_i and Y_i. for i = 1 to 31 as follows:

d_{2i+1},	d_{2i+2}	X_i,	Y_i.
0	0	+	+
0	1	+	−
1	0	−	+
1	1	−	−

NOTES

1 The period of PRU is only 63 bits, so $d_{64} = d_1$.

2 The $d_1 - d_6$ are re-initialized for each symbol, so each symbol of C-REVERB1 uses the same data.

Bits 33 and 34, which modulate the pilot carrier (i=16) are overwritten by {0,0}, generating the {+,+} constellation.

The minimum set of sub-carriers to be used is the set used for data transmission (i.e., those for which $b_i > 0$); sub-carriers for which $b_i = 0$ may be used at a reduced PSD as defined in 7.13.4. The data modulated onto each sub-carrier shall be as defined above; it shall not depend on which sub-carriers are used.

7.10 Cyclic prefix

The cyclic prefix shall be used for data and synchronization symbols beginning with segment R-RATES1 of the initialization sequence, as defined in 12.7.2.1

The last 4 samples of the output of the IDFT (x_k for $k = 61$ to 63) shall be prepended to the block of 64 samples and read out to the DAC in sequence. That is, the subscripts, k, of the DAC samples in sequence are 60...63,0...63.

7.11 Transmitter dynamic range

The transmitter includes all analog transmitter functions: the D/A converter, the anti-aliasing filter, the hybrid circuitry, and the POTS splitter. The transmitted signal shall conform to the frequency requirements described in 7.9.1 for frequency spacing.

7.11.1 Maximum clipping rate

The maximum output signal of the transmitter shall be such that the probability of the signal being clipped is no greater than 10^{-7}.

7.11.2 Noise/Distortion floor

The Signal to Noise plus Distortion (SINAD) ratio of the transmitted signal in a given sub-carrier is defined as the ratio of the rms value of the full-amplitude tone in that sub-carrier to the rms sum of all the non-tone signals in the 4.3125 kHz frequency band centered on the tone frequency. The SINAD is characterized for each sub-carrier used for transmission: SINADi represents the signal to noise plus distortion available on the transmitted signal in the i th sub-carrier.

Over the transmission frequency band, the SINAD of the transmitter in any sub-carrier (or DMT tone) shall be no less than ($3N_{upi} + 20$) dB, where N_{upi} is defined as the size of the constellation (in bits) to be used in sub-carrier i. The minimum transmitter SINAD shall be at least 38 dB (corresponding to an N_{upi} of 6) for any sub-carrier.

7.12 Transmitter spectral response

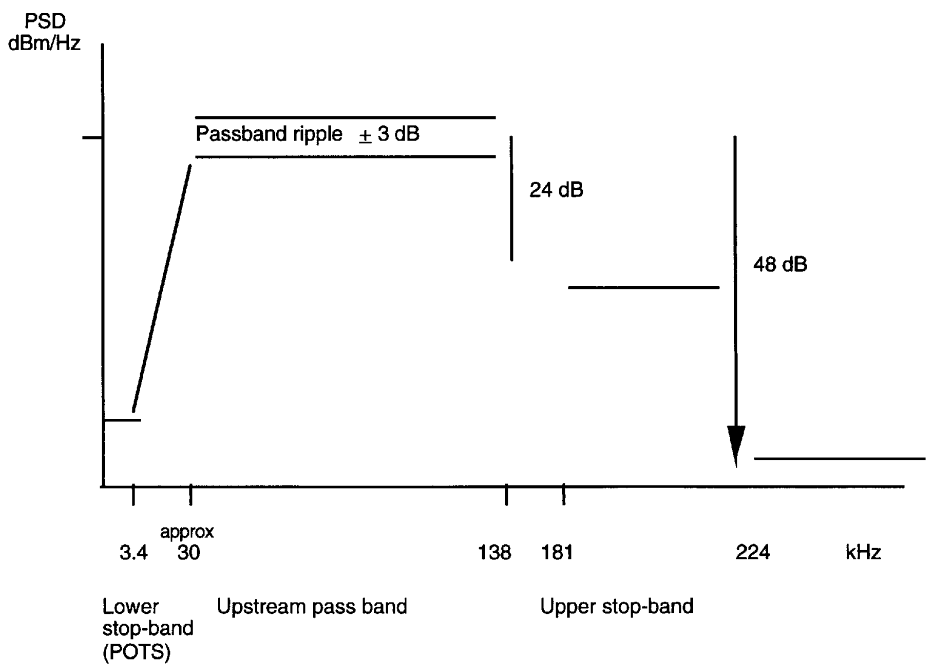


Figure 22 – ATU-R transmitter PSD mask

Figure 22 shows a representative spectral response mask for the transmitted signal. For purposes of this discussion, the pass band is defined as the frequency range over which the modem transmits. The low frequency stop band is defined as the POTS band. The high frequency stop band is defined as frequencies greater than 181 kHz, which is approximately $10\Delta f$ above the maximum pass band frequency (138 kHz).

7.12.1 Pass band response

The pass band ripple shall be no greater than + 3 dB, and the group delay variation over the pass band shall not exceed 50 µs.

7.12.2 Low frequency stop band rejection

The spectral characteristics of the output in the POTS band shall conform to the specifications in 10.3.

7.12.3 High frequency stop band rejection

The PSD in the band above 181 kHz shall be at least 24 dB below the spectral density of the pass-band mask. (see 12.4.3) The PSD in the band above 224 kHz (138 kHz+ 86 kHz) shall be at least 48 dB below the spectral density of the pass-band mask.

7.13 Transmit power spectral density and aggregate power level

There are three different PSD masks for the ATU-R transmit signal, depending on the type of signal sent. In all cases the power in the voice-band that is delivered to the POTS interface shall conform to the specification given in 10.2.

7.13.1 All initialization signals (except R-ECT) starting with R-REVERB1

The PSD in the band from 25 to 138 kHz, shall not exceed –38 dBm/Hz for a total power of not greater than 13 dBm. The power in the voice band delivered to the POTS interface shall conform to the requirements of 10.4.

7.13.2 R-ECT

Because R-ECT is a vendor-defined signal (see 12.5.4), the PSD specification shall be interpreted only as a maximum. This maximum level is –38 dBm/Hz for the band from 18 – 138 kHz. Sub-carriers 1 – 4 may be used, but the power in the voice-band that is delivered to the POTS interface shall conform to the specification given in 10.4.

7.13.3 Steady-state data signal

The transmit PSD in the frequency region from 25 – 138 kHz shall normally be –38 dBm/Hz with a maximum of –35 dBm/Hz; levels lower than –38 dBm/Hz on some sub-carriers are discretionary. The aggregate power level shall not exceed (–2 + 10 log *ncup*) dBm, where *ncup* is the number of sub-carriers used (13 dBm if all sub-carriers are used). The bits and gains table (see C-B&G in 12.8.7), calculated by, and sent from the ATU-C during initialization, may eliminate some of the sub-carriers, and finely adjust (i.e., within a ± 3 dB range) the level of others in order to equalize expected error rates on each of the sub-channels.

7.13.4 Synchronization symbol

The PSD of those sub-carriers for which $b_i > 0$ or $b_i = 0$ and $g_i > 0$ shall be the same as for the initialization signal R-REVERB1; that is, nominally –38 dBm/Hz. The PSD for those sub-carriers for which $b_i = 0$ and $g_i = 0$ shall be no higher than –48 dBm/Hz.

The PSD of a synchroniazation symbol thus differs from that of the data signals surrounding it by the g_i, which are applied only to the data carriers. These g_i are calculated for the multipoint constellations in order to equalize the expected error rate on all sub-channels, and are therefore irrelevant for most of the 4QAM signals of the synchronization symbol.

8 ADSL – POTS splitter functional characteristics

When ADSL is provided with POTS on the same twisted pair an ADSL – POTS splitting function shall be performed at each end of the line.

At the ATU-R the splitting functions are

- combining the POTS and the ATU-R transmit signals towards the U-R;
- separating the POTS and ADSL signals received from the U-R;
- protecting the POTS from voice-band interference from signals generated by both the ATU-R and ATU-C;
- protecting both ATU-R and ATU-C receivers from all POTS-related signals, particularly dial pulses, ringing and ring trip.

Protection of the ADSL receivers from those components of POTS-related signals that fall in the voice-band may be partially performed by the receivers themselves.

These functions shall be performed while meeting all requirements for POTS performance, such as echo and singing return loss, as specified in 10.1. Furthermore, these functions shall be performed in such a way that if either ATU is turned off, or if power is lost, continuity through the voice-band path is maintained, and telephone service is not interrupted.

The combination and separation of POTS and ADSL signals is achieved by low-pass and high-pass filtering. The POTS signal occupies the band up to 3.4 kHz; the bands occupied by the ADSL upsteam and downstream signals are vendor options, but leakage of the signals into the voice-band shall be constrained as defined in 10.4.

The functional characteristics of the ADSL – POTS splitter at the ATU-C are the same as those at the ATU-R, but the performance requirements may be different because of the different relative levels of signals and interferences.

9 ATU-R to service module (T_{SM}) interface requirements

Two distinctive T-interfaces are defined, see figure 23. The T_A interface preserves the ADSL channelization and the entire payload. The TTL-type signals at the T_A interface with separate clocks for each channel are intended for connection of the ADSL transceiver to other elements that sre located within a few centimeters. The T_B interface is intended to provide a simple point-to-point connection of the ATU-R to a service module, which may be 50 meters distant (greater distances are for further study). Both interfaces are optional and not necessary for compliance with the standard. An additional composite, single-channel T interface is for further study.

Functionally, the T_A-interface preserves ADSL channelization and the entire payload, and the T_B-interface is designed as a simple point-to-point interface between the ADSL entrance unit and the service module. Future issues of this standard may update this interface or specify a multipoint ATU-R to SM interface. In particular, an additional composite, single channel T-interface is for further study, and the T_A-interface may or may not be included in future issues of the standard.

9.1 T_A-interface definitions

The T_A-interface consists of a DATA and a clock (CLK) line for each of the four simplex ASX channels and for each direction of each of the three duplex LSX channels. The CLKs emanating from the ATU-R will not necessarily be smooth nor synchronous to one another. Any clock smoothing will be performed at the ATU-R to SM interface card.

The routing of proper ASX and LSX channels shall be performed by the ATU-R to SM interface card. An optional C-channel processor is specified for a multiple interface card configuration. The LS0 DATA and CLK from the ATU-R are passed to the C-channel processor before passing to the individual interface cards. The demultiplexing process of the LS0 channel can be performed by either the C-channel processor or by the individual SM's. Inversely, the upstream LS0 DATA and CLK from each interface card are collected and formatted at the C-channel processor, which in turn outputs a single upstream LS0 DATA and CLK to the ATU-R for transmission back to the ATU-C. DATAs and CLKs to and from the C-channel processor will be at standard logic levels, as specified in 9.1.1.

T_A-interface signals and timing are defined as follows:

- ASX Channels:
  - *Signal Levels:* Standard TTL logic levels;
  - *Data:* NRZ;
  - *Clock:* Standard logic levels, 50% (±15%) duty cycle;
  - *Clock polarity:* Data changes on rising clock edge;
  - *Nominal clock frequency:* 1.536 MHz, 1.544 MHz, 3.072 MHz, 4.608 MHz, or 6.144 MHz, depending on configuration (2.048 MHz optional).
- LSX Channels:
  - *Signal levels:* Standard TTL logic levels;
  - *Data:* NRZ;
  - *Clock:* Standard logic levels, 50% (±15%) duty cycle;
  - *Clock polarity:* Data changes on rising clock edge;
  - *Nominal clock frequency:* 16 kHz, 64 kHz, 160 kHz, 384 kHz, or 576 kHz, depending on configuration.

9.2 T_B-interface definitions

The T_B-interface allows a point-to-point connection that is at most 50 meters from the ADSL entrance unit to the SM; greater distances are for further study. The T_B-interface is located at the output of the ATU-R to SM interface card and consists of three separate simplex channels:

- a downstream ASX channel to the SM;
- a downstream LS0 channel to the SM;
- an upstream LS0 channel from the SM.

The optional LS1 (ISDN-BRA) channel and LS2 (H0) channel interfaces may also be provided at the T_B-interface.

T_B-interface signals and timing are defined as follows:

- ASX channel:
  - *Wire type:* Transformer-balanced, twisted-pair wire;
  - *Coding:* B8ZS;
  - *Bit rates:* 1.544, 1.536, 3.072, 4.608, or 6.144 Mbit/s depending on configuration (2.048 Mbit/s optional with G.703 interface);
  - *Maximum transmit level:* 3 volts peak.
- LS0 channel:
  - *Wire type:* Transformer-balanced, twisted-pair wire;
  - *Coding:* Biphase (Manchester);
  - *Bit Rates:* 16 or 64 kbit/s depending on configuration;
  - *Interface:* EIA RS-422.
- LS1 Channel (optional) interface: ISDN-BRA U or S/T interface.
- LS2 channel (optional) interface: Partially filled T1 with same specifications as the ASX channel above.

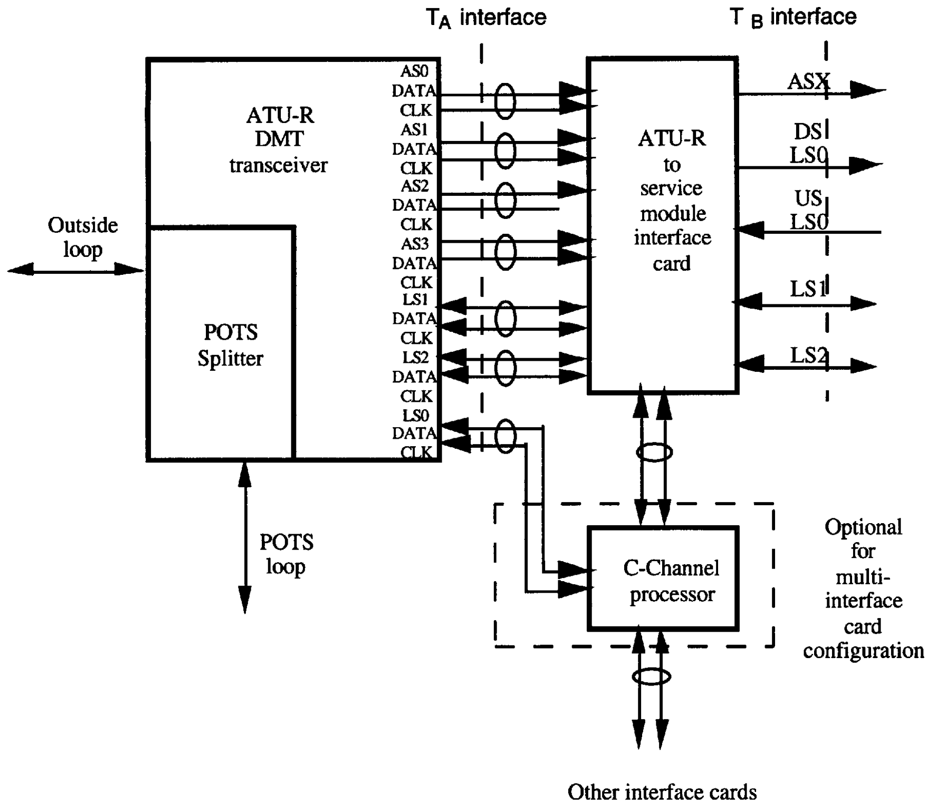


Figure 23 – ADSL entrance unit block diagram

10 Electrical characteristics

10.1 dc characteristics

All requirements of this standard shall be met in the presence of all POTS loop currents from 0 mA to 100 mA. Splitters shall pass POTS tip-to-ring dc voltages of 0 V to 105 V and ringing signals of 40 V to 150 V rms at any frequency from 15.3 Hz to 68 Hz with a dc component in the range from 0 V to 105 V.

The dc resistance from tip-to-ring at the PSTN interface with the U-C interface shorted, or at the POTS interface with the U-R interface shorted, shall be less than or equal to 25 ohms. The dc resistance from tip to ground and from ring to ground at the PSTN interface with the U-C interface open, or at the POTS interface with the U-R interface open shall be greater than or equal to 5 megohms.

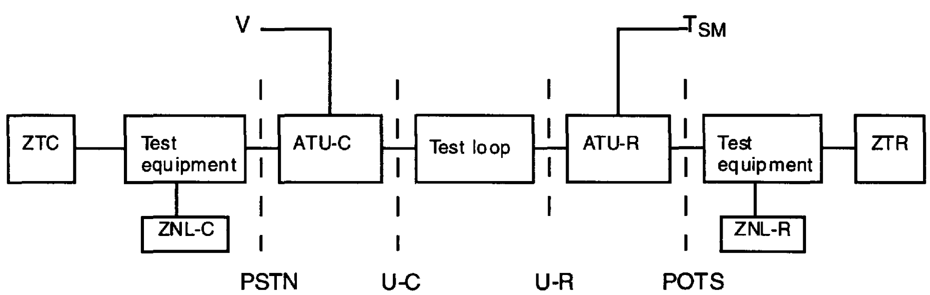
10.2 Voice-band characteristics

10.2.1 Metallic (differential mode)

A common test setup shall be used for measurement of the voice-band insertion loss, attenuation distortion, delay distortion, return loss, and noise and distortion. All measurements shall be performed between the PSTN and POTS interfaces of the ATU-C and ATU-R, respectively, with a variety of reference loops between the U-C and U-R reference points. The following loops shall be used:

- a null loop;
- ANSI T1.601 resistance-designed loops 7, 9, and 13;
- Committee T1 TR 28 CSA loops 4, 6, 7, and 8;
- 26 AWG wire pairs of lengths 0.5 kft, 2.0 kft, and 5.0 kft.

Figure 24 defines the test configuration and the value of the test components for all electrical characteristics defined in this clause unless otherwise specified; not all equipment will be required for all tests.



Where:

ZTC = 900 ohms in series with 2.16 µF for return loss measurements.
= 900 ohms for loss and noise measurements.
ZTR = 600 ohms.
ZNL-C = 800 ohms in parallel with the series connection of a 100 ohm resistor and a 50 nF capacitor.
ZNL-R =1330 ohms in parallel with the series connection of a 348 ohm resistor and a 100 nF capacitor (provisional values).

Figure 24 – Test setup for transmission and impedance measurements

10.2.1.1 Insertion loss

For each of the test loops specified in 10.1.2, and using the test set-up shown in figure 24, the insertion loss from the PSTN interface to the POTS interface shall be measured with and without the ATU-C and ATU-R connected to the test loop. The impedance of the test equipment at the PSTN interface shall be 900 ohms, and the impedance at the POTS interface shall be 600 ohms.

The increase in insertion loss at 1004 Hz on any of the test loops, due to the addition of the splitters shall be ≤ 1.0 dB.

10.2.1.2 Attenuation distortion

The variation of insertion loss with frequency of the combination of both POTS splitters shall be measured using the test setup shown in figure 24. The impedance of the test equipment at the PSTN interface shall be 900 ohms, and the impedance of the test equipment at the POTS interface shall be 600 ohms. The added attenuation distortion of the combined POTS splitters relative to loss at 1 kHz measured using each of the test loops identified above shall be not more than ± 1.0 dB at any frequency between 0.2 kHz and 3.4 kHz.

10.2.1.3 Delay distortion

The delay distortion of the POTS splitters shall be measured using the test setup of figure 24. The increase in envelope delay distortion between 0.6 kHz and 3.2 kHz caused by the two POTS splitters in each of the test loops shall be less than 200 µS.

10.2.1.4 Return loss

The ERL, SRL-low and SRL-high shall be measured at the PSTN and POTS interfaces, for each of the 10 loops (except the null loop), under the following conditions:

- at the PSTN interface with both the ATU-C and ATU-R splitters installed and the ATU-R terminated in ZTR;
- at the PSTN interface with the ATU-C splitter installed and the ATU-R terminated in ZTR;
- at the POTS interface with both splitters installed and the ATU-C terminated in ZTC;
- at the POTS interface with the ATU-R splitter installed and the ATU-C terminated in ZTC.

The ERL, SRL-low and SRL-high for each of these conditions shall exceed the values contained in table 29 for each loop.

Table 29 – Minimum voice-band return losses at PSTN and POTS interfaces

Measurement location	ATU-C splitter	ATU-R splitter	ERL (dB)	SRL-low (dB)	SRL-high (dB)
PSTN	in	in	8	5	5
PSTN	in	out	8	5	5
POTS	in	in	6	5	5
POTS	out	in	6	5	5

Furthermore, it is desirable that the mean values of the ERL, SRL-low and SRL-high over the full suite of 10 loops be degraded as little as possible from the mean values with no splitters present. The permissible amount of degradation is for further study.

10.2.1.5 Noise and distortion

The distortion contributed by the two POTS splitters shall be measured using the test configuration of figure 24 and the null loop.

With an applied holding tone at –9 dBm, the Signal-to-C-notched noise ratio shall exceed 42 dB, and the second- and third-order intermodulation distortion products shall be at least 57 dB and 60 dB, respectively, below the received signal level.

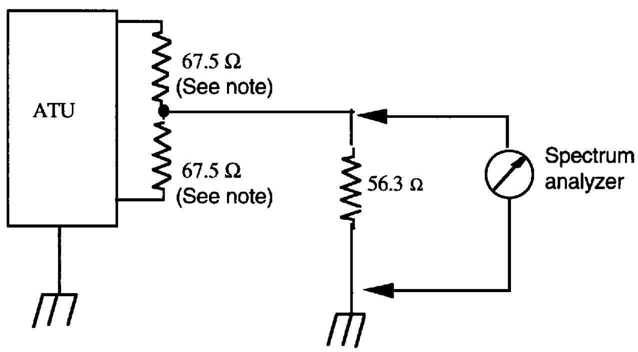
NOTE – While these measurements are often made with a holding tone level of –13 dBm, a level of –9 dBm is specified for this application because it represents the maximum allowed signal power from a voice-band modem onto a POTS line.

10.2.2 Longitudinal (common mode)

10.2.2.1 Longitudinal output voltage

The ATU-C shall present to the U-C interface, and similarly the ATU-R shall present to the U-R interface, a longitudinal component whose rms voltage in any 4 kHz band averaged in any 1 second period, is less than –50 dBv over the frequency range 100 Hz to 1 MHz.

Figure 25 defines a measurement method for longitudinal output voltage. For direct use of this test configuration, the ATU shall be able to generate a signal in the absence of a received signal. The ground reference for these measurements shall be the building or green wire ground at the ATU.



NOTE – These resistors shall be matched to better than 0.1% tolerance.

Figure 25 – Measurement method for longitudinal output voltage

10.2.2.2 Longitudinal balance

Longitudinal balance at the PSTN and POTS interfaces shall be > 58 dB from 0.2 kHz to 1 kHz and >53 dB at 3 kHz, measured in accordance with IEEE Standard 455.

10.3 ADSL band

10.3.1 Return loss

At the U-C and U-R reference points the nominal impedance in the ADSL band shall be 100 ohms. The return loss relative to 100 ohms in the frequency range from 30 – 1100 kHz shall be ≥ 10 dB.

10.3.2 Longitudinal balance

Longitudinal balance at the U-C and U-R interfaces shall be > 40 dB over the frequency range 20 kHz to 1100 kHz with the PSTN and POTS interfaces terminated with ZTC and ZTR respectively. Longitudinal balance is given by the equation

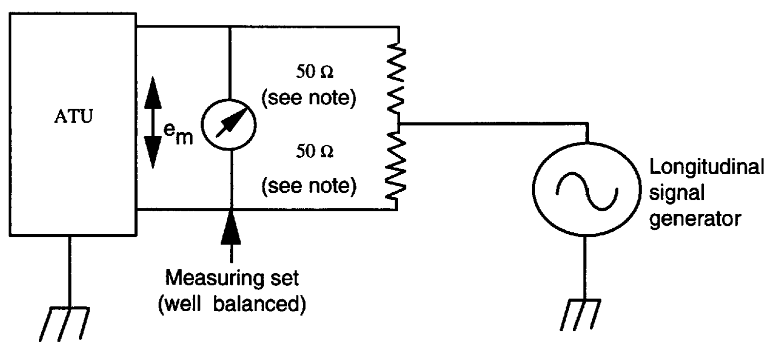
$$LBal = 20 \log \left| \frac{e_l}{e_m} \right| \text{dB}$$

where:

e_l = the applied longitudinal voltage (referenced to the building or green wire ground of the ATU);

e_m = the resultant metallic voltage appearing across a terminating resistor.

Figure 26 defines a measurement method for longitudinal balance in the ADSL band. For direct use of this test configuration, measurements shall be performed with the ATU powered up but inactive, driving 0 Volts.



NOTE – These resistors to be matched to better than 0.03% tolerance

Figure 26 – Measurement method for longitudinal balance above 25 kHz

10.4 ADSL noise interference into the POTS circuit

10.4.1 Steady state noise

The idle channel noise on the POTS circuit shall not exceed 18 dBrnC at either the POTS or the PSTN interfaces with the ADSL system installed whether operating or not operating.

The power at any single frequency less than 15 kHz as measured by test equipment with a bandwidth of 30 Hz shall not exceed the greater of 0 dBrn or 10 dB below the measured idle channel noise.

10.4.2 Impulse noise

During initialization and operation of the ADSL system, with no holding tone applied to the circuit under test, there shall be no more than fifteen counts in fifteen minutes at a threshold of 47 dBrnCO at either the PSTN or the POTS interface.

During initialization and operation of the ADSL system, with a –13 dBm0 holding tone at 1004 Hz applied to the circuit under test, there shall be no more than fifteen counts in fifteen minutes at a threshold of 65 dBrnCO at either the PSTN or the POTS interface.

These impulse noise requirements shall be met with each of the test loops specified in 10.2.1 with the ADSL system forced to re-initialize once per minute during the test interval.

11 Operations and maintenance

11.1 Embedded operations channel (eoc) requirements

An embedded operations channel for communication between the ATU-C and ATU-R shall be used for in-service and out-of-service maintenance, and for the retrieval of a limited amount of ATU-R status information and ADSL performance monitoring parameters. The eoc may also be used in the future to extend maintenance and performance monitoring to the service module(s) at the customer premises. The eoc channel is shared with user channel synchronization control of the fast data buffer. This clause describes the eoc functions, protocol, and commands. Insertion of eoc frames within the ADSL data frames is described in 6.2 and 7.2.

11.1.1 eoc organization and protocol

The ADSL eoc is organized into eoc frames, which are transmitted within the synchronization control overhead of the fast data buffer, to allow the ATU-C (acting as master of the link) to invoke commands and the ATU-R (acting as slave) to respond to the commands.

When it is not required for synchronization control, crc, or fixed indicator bits, the "fast" byte of two successive ADSL frames, beginning with an even-numbered frame as described in 6.2 and 7.2, shall be used to transmit one eoc frame, consisting of 13 bits. For the allowable user data configurations (see 5.3), up to 32 eoc frames can be transmitted per ADSL superframe. The eoc channel rate will vary from some minimum rate that will be dependent on the vendor's synchronization control algorithm (to implement the synchronization control described in 6.2) to about 23.7 kbit/s.

The ATU-C, as master, determines the eoc rate of the ADSL link; therefore only one eoc frame shall be inserted in the upstream direction (by the ATU-R) for each received eoc frame. One exception to this is for the "dying gasp" message, which is the only autonomous message currently allowed from the ATU-R and is inserted as soon as upstream "fast" bytes are available.

The 13 bits of the eoc frame are defined in table 30. The assignment of these bits to positions within the "fast byte" is defined in 6.2 and 7.2. The eoc protocol states are defined in 11.1.4.

Table 30 – eoc bit functions

Bit position	#Bits	Description	Notes
1,2	2	Address field	Can address 4 locations
3	1	Data (0) or opcode (1) field	Data used for read/write
4	1	Byte parity field Odd (1) or even (0)	Multibyte transmission
5	1	Unspecified for ATU-C (set to 1) (see note) Autonomous ATU-R message (0) or ATU-R response to eoc protocol (1)	Reserved for future use at ATU-C Used by ATU-R to send "dying gasp"
6-13	8	Information field	58 opcodes, 8 bits data
NOTE – The only autonomous message currently defined for the ATU-R is the "dying gasp" (11.1.4.4). Other uses of the eoc5 bit are for further study.			

11.1.2 eoc frame structure

The eoc frame shall contain 5 fields, defined in the following subclauses.

11.1.2.1 Address field

The two bits of the address field can address up to four locations. Only two locations are presently defined:

- 11 for the ATU-C;
- 00 for the ATU-R.

10 and 01 are reserved for future use.

11.1.2.2 Data or opcode field

A 1 in this field indicates that the information field of the current eoc frame contains data; a 0 that it contains an operation code for an ADSL eoc message.

11.1.2.3 Byte parity field

For the first byte of data that is to be either read or written, this bit shall be set to 1 to indicate "odd" byte. For the next byte, it is set to 0 to indicate "even" byte and so on, alternately. This bit helps to speed up multi-byte reads and writes of data by eliminating the need for intermediate opcodes to indicate to the far end that the previous byte was successfully received.

11.1.2.4 Unspecified bit (ATU-C) / ATU-R autonomous message field

At the ATU-C, this field is reserved for future use, and until specified otherwise shall be set to 1 in all eoc frames transmitted by the ATU-C. At the ATU-R, a 1 in this field shall designate that the current eoc frame is an eoc protocol response (slave) message; a 0 that it is an autonomous message that does not disturb the current state of the eoc protocol at either the ATU-C or the ATU-R. The only autonomous message currently defined for the ATU-R is the "dying gasp" (11.1.4.4).

11.1.2.5 Information field

Up to 58 different messages or 8 bits of binary or ASCII data may be encoded in the information field.

The message set is restricted to codes that provide a minimum Hamming distance of 2 between all opcodes, and a minimum distance of 3 between certain critical codes and all other codes.

11.1.3 eoc message sets

The ATU-C sends commands to the ATU-R to perform certain functions. Some of these functions require the ATU-R to activate changes in the circuitry (e.g., to send crc bits that are corrupt). Other functions that can be invoked are to read from and write into data registers located at the ATU-R. The data registers are used for reading status- or performance-monitoring parameters from the ATU-R, or for limited maintenance extensions to the CI wiring distribution network or service modules.

Some of these commands are "latching", meaning that a subsequent command shall be required to release the ATU-R from that state. Thus, multiple ADSL eoc-initiated actions can be in effect simultaneously. A separate command, "Return To Normal", shall be used to unlatch all latched states. This command is also used to bring the ADSL system to a known state, the idle state, when no commands are active in the ATU-R location. To maintain the latched state, the command "Hold State" shall be continually sent.

The ATU-C always issues the commands, and the ATU-R responds by acknowledging to the ATU-C that the message was received correctly.

11.1.3.1 eoc message set requirements

Messages that may be sent by the ATU-R and ATU-C in response to correctly received messages are:

– *Hold State:* This message shall be sent by the ATU-C to the ATU-R to maintain the ATU-R eoc processor and any active ADSL eoc-controlled operations (such as latching commands) in their present state;

– *Return to Normal (Idle Code):* This message releases all outstanding eoc-controlled operations (latched conditions) at the ATU-R and returns the ADSL eoc processor to its initial state. This code is also the message sent during idle states;

– *Unable to Comply Acknowledgment:* The ATU-R shall send this message when it receives an ADSL eoc message that it cannot perform either because it does not recognize or implement the command or because the command is unexpected, given the current state of the ADSL eoc interface. An example of an unexpected command is one that indicates that the information field contains data, but that was not preceded by a "Write Data" command;

– *Request Corrupt crc:* This message requests the ATU-R to send corrupt crcs to the ATU-C until canceled by the "Request End of Corrupt crc" or "Return to Normal" message. In order to allow multiple ADSL eoc-initiated actions to be in effect simultaneously, the "Request corrupt crc" command shall be latching;

– *Request End of Corrupt crc:* This message requests the ATU-R to stop sending corrupt crcs toward the ATU-C;

– *Notify Corrupted crc:* This message notifies the ATU-R that intentionally corrupted crcs will be sent from the ATU-C until cancellation is indicated by "Notify End of Corrupted crc" or "Return to Normal";

– *Notify End of Corrupted crc:* This message notifies the ATU-R that the ATU-C has stopped sending corrupted crcs;

– *Perform Self Test:* This message requests the ATU-R to perform a self test. The result of the self test is stored in a register at the ATU-R. After the ATU-R self test, the ATU-C reads the test results from the ATU-R register;

– *Write Data (Register #):* This message directs the ATU-R to enter the Data Write Protocol state and receive data in the register specified by the Opcode;

– *Read Data (Register #):* This message directs the ATU-R to enter the Data Read Protocol state to transmit data to the ATU-C from the register specified by the Opcode;

– *Next Byte:* This message is sent by the ATU-C in data read or data write mode after the ATU-R has acknowledged the previously sent read or write data command. This message is continually sent by the ATU-C when it is in the data read or data write mode, toggling bit four for multi-byte data, until all data have been read;

– *End of Data:* This message is sent by the ATU-C after it has sent all bytes of data to the ATU-R. This message is also sent by the ATU-R in response to a "Next Byte" message from the ATU–C that is received after all bytes have been read or written from the currently addressed ATU-R register;

– *Vendor Proprietary Opcodes:* Four opcodes have been reserved for vendor proprietary use. The ATU-C shall read the ID (identification) code register of the ATU-R to ensure compatibility between the ATUs before using proprietary opcodes;

– *Undefined Command Codes:* All command codes not defined are reserved for future use, and shall not be used for any purpose.

11.1.3.2 eoc opcode messages

Table 31 – eoc opcode messages

(HEX)	Opcode meaning	Notes
01	Hold state	To continue sending corrupt crcs
F0	Return all active conditions to normal	Also used as "idle code"
02	Perform "self test"	Self test results are stored in register
04	Unable to comply (UTC)	Unrecognizable command
07	Request corrupt crc (see note)	
08	Request end of corrupt crc	
0B	Notify corrupt crc (see note)	
0D	Notify end of corrupt crc	
0E	End of data	
10	Next byte	
E7	Dying Gasp	Sent by ATU-R only
(20,23,25,26) (29,2A,2C,2F) (31,32,34,37) (38,3B,3D,3E)	Write data register numbers 0 through F	
(40,43,45,46) (49,4A,4C,4F) (51,52,54,57) (58,5B,5D,5E)	Read data register numbers 0 through F	
(19,1A,1C,1F)	Vendor proprietary protocols	
NOTE – Latching conditions.		

The eoc opcode messages specified in table 31 guarantee a minimum Hamming distance of 2 (by requiring odd parity for all but two critical codes) between all opcodes, a minimum Hamming distance of 3 between the "Return to Normal" (or "idle") code and all other codes, and a minimum Hamming distance of 3 between the "Dying Gasp" code and all other codes.

The following hexadecimal codes, which still maintain a minimum Hamming distance of 2, shall not be used unless specified at some future time: 13, 15, 16, 80, 83, 85, 86, 89, 8A, 8C, 8F.

11.1.3.3 Data registers in the ATU-R

Table 32 summarizes the ATU-R data registers and their applications.

Table 32 – ATU-R data registers

REG # (HEX)	USE	LENGTH	DESCRIPTION
0	Read (R)	6 bits	ID code (ATU-R): bits 0-3: vendor IDs 0 through F, bits 4,5: reserved for future use (set to 0)
1	R	6 bits	version number : bits 0-3: version numbers 0 through F, bits 4,5: reserved for future use (set to 0)
2	R	256 bits	Serial #
3	R	1 byte	Self test results
4	Read/Write (R/W)	Vendor Defined	Vendor defined
5	R/W	Vendor Defined	Vendor defined
6	R	1 byte	line attenuation
7	R	1 byte	Estimated margin
8	R	30 bytes	ATU-R Configuration (Note 1) : one byte each for B_F(AS0), B_I(AS0), B_F(AS1), B_I(AS1), B_F(AS2), B_I(AS2), B_F(AS3), B_I(AS3), B_F(LS0), B_I(LS0), B_F(LS1), B_I(LS1), B_F(LS2), B_I(LS2) FS(LS2) (downstream), B_F(LS0), B_I(LS0), B_F(LS1), B_I(LS1), B_F(LS2), B_I(LS2) FS(LS2) (upstream), R_{dsf}, R_{dsi}, S, I (downstream), R_{usf}, R_{usi}, S, I (upstream)
9	R	4 bits	Service module maintenance indicators (Note 2): bit 0: SM downstream sync bit 1: SM downstream no sync bit 2: SM upstream sync bit 3: SM upstream no sync
A – F	reserved	reserved	

NOTES

1 ATU configuration parameter set (B_F( ), B_I( ), FS(LS2), R_{dsf}, R_{dsi}, R_{usf}, R_{usi}, S, I) are defined in 6.2 and 7.2.

2 SM sync – no sync indicators defined in 11.5.

3 Registers A through F are reserved for future use; ATU-R shall respond UTC (unable to comply) if requested to read or write one of these registers.

11.1.4 eoc protocol states

The ADSL eoc protocol operates in a repetitive command and response mode. The ATU-C acts as the master and issues commands; the ATU-R acts as slave, and responds to the commands issued by the ATU-C. Three identical properly-addressed consecutive messages shall be received before an action is initiated. Only one command and only three or fewer messages, under the control of the ATU-C, shall be outstanding (i.e., unacknowledged) at any one time. (This restriction on the number of messages guarantees that an ATU-R with fewer opportunities to insert eoc frames into the upstream path will be able to acknowledge all eoc messages from the ATU-C.)

Three types of responses are allowed from the ATU-R; therefore three command and response protocol states are allowed on the ADSL eoc. The three states are:

- message/echo-response protocol state;
- message/unable-to-Comply-response protocol state;
- message/data-response protocol state.

In addition to these three states, one autonomous message shall be allowed from the ATU-R to the ATU-C to indicate "dying gasp". This message does not change the protocol state, nor does it count as a response to any ATU-C message; however, other actions (e.g., an automatic reset at the ATU-C) taken as a result of receiving this message may lead to a change of state (e.g., back to idle).

The eoc protocol shall enter the Message/Echo-response protocol state when the ATUs transition from the initialization and training sequence to steady state transmission. The ATU-C shall continuously send an appropriately addressed message. In order to cause the desired action in the addressed location, the ATU-C shall continue to send the message until it receives three identical consecutive eoc frames from the addressed location. The command and response protocol for that message shall be completed before a new message, which may induce a different protocol state in the ATU-R, may be issued.

11.1.4.1 Message / echo-response protocol state

To initiate an action at the ATU-R, the ATU-C shall begin sending eoc messages with the Data/opcode set to 0, and with the appropriate message opcode in the information field.

The ATU-R shall initiate action when, and only when, three identical, consecutive, and properly addressed eoc frames that contain a message recognized by the ATU-R have been received. The ATU-R shall respond to all received messages. The response shall be an echo of the received ADSL eoc message. The combination of the ATU-C sending an ADSL eoc frame and the ATU-R echoing the frame back comprises the message/echo-response protocol state.

For the ATU-C to confirm correct reception of the message by the ATU-R, the message / echo-response ADSL eoc protocol state shall be repeated until the master node receives three identical and consecutive echoes. This serves as an implicit acknowledgment to the ATU-C that the ATU-R has correctly received the transmitted message and is acting on it. This completes the Message / Echo-response protocol mode.

Because eoc frames are inserted into ADSL frames only when the "fast byte" is available, the amount of time it takes to complete a message under error-free conditions will depend on the vendor's synchronization control algorithm, on the number of signals allocated to the fast buffer, and on the rates of those signals.

The ATU-C may continuously send the activating message after the receipt of the three valid echoes, or alternatively, it may switch to sending the "Hold State" message. If the message was one of the latching commands, then the ATU-R shall maintain the commanded condition until the ATU-C issues the appropriate command that ends the specific latched condition or until the ATU-C issues the "Return to Normal" command (at which time all latched conditions in the ATU-R shall be terminated).

11.1.4.2 Message / unable-to-comply response protocol state

When the ATU-R does not support a message that it has received three times identically and consecutively, it shall respond with the Unable-To-Comply (UTC) ADSL eoc response message with its own address in lieu of a third identical and consecutive echo. In this manner the ATU-R will switch to the message / UTC-response protocol state.

The transmission by the ATU-R and reception by the ATU-C of three identical, consecutive, properly-addressed Unable-To-Comply messages constitutes notification to the ATU-C that the ATU-R does not support the requested function, at which time the ATU-C may abandon its attempt.

11.1.4.3 Message / data-response protocol state

The ATU-C can either write data into, or read data from the ATU-R memory.

11.1.4.3.1 Data read protocol

To read data from the ATU-R, the ATU-C shall send an appropriate read opcode message to the ATU-R that specifies the register to be read. After receiving three identical and consecutive acknowledgments, the ATU-C shall request the first byte to be sent from the ATU-R by sending "Next Byte" messages with bit four set to 1, indicating a request for an "odd" byte. The ATU-R shall respond to these "Next Byte" messages by echoing them until it has received three such messages consecutively and identically. Beginning with the third such reception, the ATU-R shall respond by sending the first byte of the register in the information field of an ADSL eoc frame with bit four set to 1 to indicate "odd byte" and with bit 3 set to 0 to indicate that the eoc frame is a data frame (as opposed to a frame that contains an opcode in the information field). The ATU-C continues to send the "Next Byte" message with bit four set to "odd byte", and the ATU-R continues to respond with a data frame containing the first byte of data and bit four equal to "odd byte", until the ATU-C has received three consecutive and identical data frames with bit four set to "odd byte".

If there are more data to be read, the ATU-C shall request the second byte of data by sending "Next Byte" messages with bit four set to 0 ("even byte"). The ATU-R echoes all messages received until three such "Next Byte" messages have been received, and on the third consecutive and identical "Next Byte" message, the ATU-R starts sending data frames containing the second byte of the register with bit four set to 0. The ATU-C continues to send the "Next Byte" message with bit four set to "even byte", and the ATU-R continues to respond with a data frame containing the identical data frames with bit four set to "even byte".

The process continues for the third and all subsequent bytes with the value of bit four toggling from "odd byte" to "even byte" or vice versa, on each succeeding byte. Each time bit four is toggled, the ATU-R shall echo for two correct frames, and starts sending the data frame on the third reception. The process ends only when all data in the register have been read.

To continue reading data, once the ATU-R is in the data read mode, the only message that the ATU-C is allowed to send is the "Next Byte" message with bit four toggling. To end the data read mode abnormally, the ATU-C shall send either "Hold State" or "Return to Normal", depending on whether any latched states are to be retained. If the ATU-R receives any other message three times consecutively and identically while it is in data read mode, then it shall go into a UTC mode.

If, after all bytes have been read from the ATU-R register, the ATU-C continues to send the "Next Byte" message with bit four toggled, then the ATU-R shall send an "End of Data" message (with bit three set to 1 indicating opcode).

The data read mode ends either when the ATU-C has received the last requested data byte three times consecutively and identically, or when the ATU-C has received three consecutive "End of Data" messages with bit three set to *1*. The ATU-C shall then switch over to a known state with the "Hold State" or "Return to Normal" message, and the ATU-R shall release the register and end the data read mode.

11.1.4.3.2 Data write protocol

To write data to the ATU-R's memory, the ATU-C shall send a "Write Data" opcode message to the ATU-R that specifies the register to be written. When the ATU-R acknowledges with three consecutive echo messages, the ATU-C shall send the first byte of data. The ATU-R shall acknowledge the receipt of the byte with an echo of the message. After the ATU-C is satisfied with three identical and consecutive correct echo responses, it shall start sending the next byte of data. Each time the ATU-C receives three identical and consecutive correct data echo responses, it shall switch to sending the next byte of data. It shall also toggle the "odd/even" bit accordingly. ("Next Byte" messages are not used in the Data Write mode). The ATU-C shall end the write mode with the "End of Data" message indicating to the ATU-R to release the register and end the data write mode.

11.1.4.4 "dying gasp"

When circuits in the ATU-R detect that electrical power has been shut off, the ATU-R shall insert eoc frames into the ADSL upstream data to implement a "dying gasp". The "dying gasp" eoc frames shall have bit 5 set to 0 to indicate autonomous message, bit 3 set to 1 to indicate opcode, and shall contain the "dying gasp" opcode (see table 31) in the information field. At least six of these frames are inserted in the next (twelve) available ADSL upstream "fast" bytes beginning with an even-numbered frame, regardless of the number of eoc frames received in the downstream channel.

Sending the "dying gasp" shall not cause the ATU-R to change the eoc protocol state, nor shall receiving it cause the ATU-C to immediately change state.

11.2 In-service performance monitoring and surveillance

The following terminology is used in this standard (see figure 27):

– *Near-end:* Near-end means performance of the loop-side received signal at the input of the ATUs;

– *Far-end:* Far-end means performance of the downstream loop-side received signal at the input of the ATU-R, where this performance is reported to the ATU-C in upstream overhead indicators (see figure 27). Far-end also means performance of the upstream loop-side received signal at the input of the ATU-C, where this performance is reported to the ATU-R in downstream overhead indicators; this case is a mirror image of the above;

– *Primitives:* Primitives are basic measures of performance, usually obtained from digital signal line codes and frame formats, or as reported in overhead indicators from the far-end. Performance primitives are categorized as events, anomalies and defects. Primitives may also be basic measures of other quantities (e.g., ac or battery power), usually obtained from equipment indicators;

– *Events:* Events are bit error related primitives that do not affect service performance (fec and fecc);

– *Anomalies:* Anomalies are bit error related primitives that affect service performance (crc and febe);

– *Defects:* Defects are signal or framing related primitives that are more disruptive to service than anomalies (los, sef, rdi).

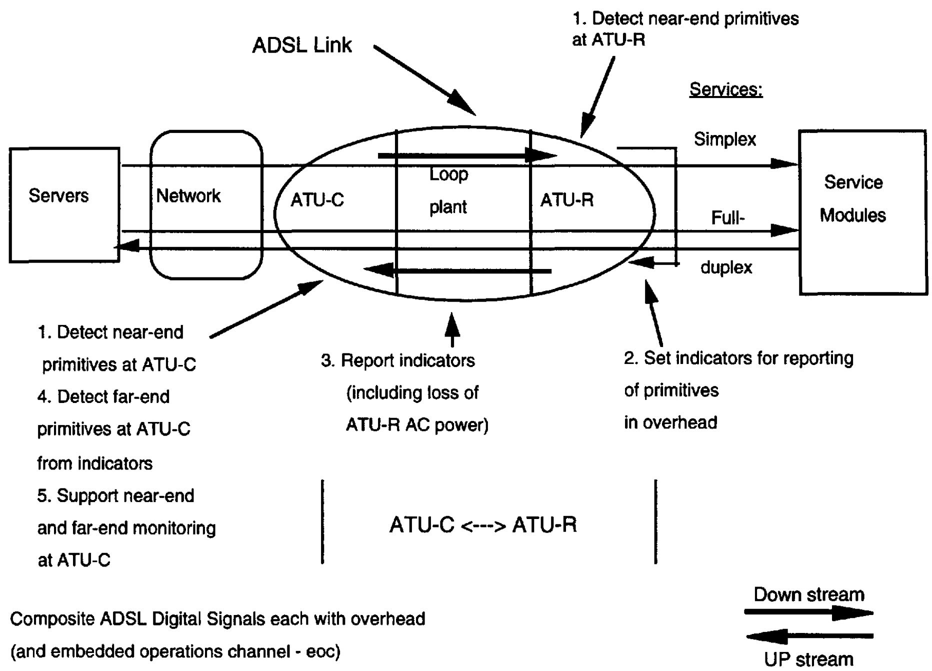


Figure 27 – In-service surveillance of the ADSL link shown from the standpoint of the ATU-C

11.2.1 Digital transmission related primitives

11.2.1.1 Near-end events

Two near-end events are defined:

– *Forward error correction (fec)-i:* An fec-i event occurs when a received FEC code for the interleaved data stream indicates that errors have been corrected;

– *Forward error correction (fec)-ni:* An fec-ni event occurs when a received FEC code for the non-interleaved data stream indicates that errors have been corrected.

11.2.1.2 Far-end events

Similarly, two far-end events are defined:

– *Far-end forward error correction (ffec)-i:* ffec-i shall be reported by the fecc-i indicator, which is coded with one indicator bit (1 indicating that no event is present in the previous superframe; 0 indicating that an event is present) in the overhead, and reported once per ADSL superframe.

– *Far-end forward error correction (ffec)-ni:* ffec-ni shall be reported by the fecc-ni indicator, which is coded and reported in the same way as an fecc-i.

11.2.1.3 Near-end anomalies

Two near-end anomalies are defined:

– *Cyclical redundancy check (crc)-i error:* A crc-i anomaly occurs when a received CRC-8 code for the interleaved data stream is not identical to the corresponding locally generated code;

– *Cyclical redundancy check (crc)-ni error:* A crc-ni anomaly occurs when a received CRC-8 code for the non-interleaved data stream is not identical to the corresponding locally generated code.

11.2.1.4 Far-end anomalies

Similarly, two far-end anomalies are defined:

– *Far-end block error (febe)-i:* A crc-i anomaly detected at the far-end shall be reported by the febe-i indicator, which is coded with one indicator bit (*1* indicating that no event is present in the previous superframe; *0* indicating that an event is present) in the overhead, and reported once per ADSL superframe;

– *Far-end block error (febe)-ni:* A crc-ni anomaly detected at the far-end shall be reported by the febe-ni indicator, which is coded and reported in the same way as an febe-i.

11.2.1.5 Near-end defects

Two near-end defects are defined:

– *Loss-of-signal (los):* A pilot tone reference power shall be established by averaging the ADSL pilot tone power for 0.1 after the start of steady state data transmission (i.e., after initialization). An LOS defect then occurs when the received ADSL pilot tone power, averaged over a 0.1 s period, is 6 dB or more below the reference power. An LOS defect shall terminate when the received pilot tone power, averaged over a 0.1 s period is less than 6 dB below the reference;

– *Severely errored frame (sef):* An sef defect occurs when the content of two consecutively received ADSL synchronization symbols does not match the expected content. An sef defect terminates when the content of two consecutively received ADSL synchronization symbols matches the expected content.

11.2.1.6 Far-end defects

– *Loss-of-signal (los):* An LOS defect as detected at the far-end shall be reported by the los indicator, which is coded with one indicator bit (1 indicating that no defect is being reported; 0 indicating that a defect is being reported) in the overhead, and reported for six consecutive ADSL superframes;

A far-end los defect occurs when 4 or more out of 6 contiguous los indicators are received set to 0. A far-end los defect terminates when 4 or more out of 6 contiguously received los indicators are set to 1;

– *Remote defect indication (rdi):* An sef defect is reported by the rdi indicator, which is coded with one indicator bit (1 indicating that no event is present in the previous superframe; 0 indicating that an event is present) in the overhead, and reported once per ADSL superframe. An rdi defect occurs when a received rdi indicator is set to 0. An rdi defect terminates when a received rdi indicator is set to 1.

11.2.2 Other primitives

11.2.2.1 Other near-end primitives

Three other near-end primitives are defined:

– *Attenuation (atn):* An atn primitive is the difference in dB between the power received at the near-end and that transmitted from the far-end. Signal power in dBm is the sum of all active DMT subcarrier powers averaged over a 1 s period. An atn primitive is expressed as an integer number of dB ranging from a minimum of 0 to a maximum of 60 dB, so as to correspond to a sensible range of atn;

– *Signal-to-Noise ratio (snr) margin:* An snr margin primitive represents the amount of increased noise (in dB) relative to the noise power that the system is designed to tolerate and still meet the target BER of 10^{-7}, accounting for all coding (e.g., Trellis code, FEC) gains included in the design. An snr margin primitive is expressed as an integer number of dB ranging from a minimum of x dB to a max. of y dB, with x and y for further study so as to correspond to a sensible range of SNR;

– *Loss-of-power (lpr):* An lpr primitive occurs when ATU power drops to a level equal to or below the manufacturer-determined minimum power level required to ensure proper operation of the ATU. An lpr primitive terminates when the power level exceeds the manufacturer-determined minimum power level.

11.2.2.2 Other far-end primitives

Similarly, three other far-end primitives are defined:

– *Attenuation (atn):* An atn primitive as detected at the far-end shall be reported by the atn indicator. A far end atn primitive occurs when one atn indicator is received with value not less than x and not more than y dB, with the values of x and y for further study. The atn indicator is reported in an eoc message;

– *Signal-to-noise Ratio (snr) margin:* An snr margin primitive as detected at the far-end shall be reported by the snr margin indicator in an eoc message. A far-end snr margin primitive occurs when one snr margin indicator is received with value not less than *x* and not more than *y* dB, with the values of *x* and *y* for further study;

– *Loss-of-power (lpr):* An lpr primitive as detected at the far-end shall be reported by the lpr indicator. A far-end lpr primitive occurs when 4 out of 6 contiguous lpr indicators are received. A far-end lpr primitive terminates if the near signal remains present, i.e., if the received 4 out of 6 contiguous lpr indicators are not followed by any near-end los defects in the next 0.5 s (see los defect definition in 11.2.1.5);

The lpr indicator is coded as an 8 bit emergency priority message in the ATU-R to ATU-C overhead, and is reported in the next 6 available outgoing eoc frames (see the eoc protocol for "dying gasp" in 11.1.4.4).

11.2.3 Failures and failure count parameters

11.2.3.1 Near-end failures and failure count parameters

At the ATU-R, near-end failures shall be manifested as LOS or LOF failure (e.g., red light), no failures (e.g., green light), and LPR (e.g., no lights); failure count parameters are optional.

The following near-end failures and failure count parameters are required at the ATU-C:

– *Loss-of-signal (LOS):* An LOS failure is declared after 2.5 ± 0.5 seconds of contiguous los defect, or, if los defect is present when the criteria for LOF failure declaration have been met (see LOF definition below). An LOS failure is cleared after 10 ± 0.5 seconds of no los defect. An LOS failure count is the number of occurrences of an LOS failure event,

where a failure event occurs when the failure is declared, and ends when the failure clears;

– *Loss-of-frame (LOF):* An LOF failure is declared after 2.5 ± 0.5 seconds of contiguous sef defect, except when an los defect or failure is present (see LOS definition above). A LOF failure is cleared when LOS failure is declared, or after 10 ± 0.5 seconds of no sef defect. An LOF failure count is the number of occurrences of an LOF failure event, where a failure event occurs when the failure is declared, and ends when the failure clears;

– *Loss-of-power (LPR):* An LPR failure is declared after the occurrence of an lpr primitive, followed by other-to-be determined conditions. This definition is under study. An LPR failure count is the number of occurrences of an LPR failure event, where a failure event occurs when the failure is declared, and ends when the failure clears.

11.2.3.2 Far-end failures and failure count parameters

The following far-end failures and failure count parameters are required at the ATU-C (ATU-R is at the far-end), and are optional at the ATU-R (ATU-C is at the far-end).

– *Loss-of-signal (LOS):* A far-end LOS failure is declared after 2.5 ± 0.5 seconds of contiguous far-end los defect, or, if far-end los defect is present when the criteria for LOF failure declaration have been met (see below). A far-end LOS failure is cleared after 10 ± .5 seconds of no far-end los defect. An LOS failure count is the number of occurrences of an LOS failure event, where a failure event occurs when the failure is declared, and ends when the failure clears;

– *Remote failure indication (RFI):* An RFI failure is declared after 2.5 ± 0.5 seconds of contiguous rdi defect, except when a far-end los defect or failure is present (see above). A RFI failure is cleared when far-end LOS failure is declared, or after 10 ± 0.5 seconds of no rdi defect. An RFI failure count is the number of occurrences of a RFI failure event, where a failure event occurs when the failure is declared, and ends when the failure clears;

– *Loss-of-power (LPR):* An LPR failure is declared after receiving a far-end lpr (dying gasp-like) primitive followed by 2.5 ± 0.5 seconds of contiguous near-end los defect. AN LPR failure is cleared after 10 ± 0.5 seconds of no near-end los defect. An LPR failure count is the number of occurrences of an LPR failure event, where a failure event occurs when the failure is declared, and ends when the failure clears.

11.2.4 Quality-of-service (QOS) parameter

11.2.4.1 Near-end QOS parameter

The near-end errored-second (ES) parameter is a count of one-second intervals containing one or more crc-i or crc-ni anomalies, or one or more los or sef defects. It is required at the ATU-C, and is optional at the ATU-R.

11.2.4.2 Far-end QOS parameter

The far-end errored-second (ES) parameter is a count of one-second intervals containing one or more febe-i or febe-ni anomalies, or one or more far-end los or rdi defects. It is required at the ATU-C (ATU-R is at the far-end), and is optional at the ATU-R (ATU-C is at the far-end).

11.2.5 Test parameters

The attenuation (ATN) and signal-to-noise ratio (SNR) margin test parameters apply to on-demand test requests; e.g., to check for adequate physical media performance margin at acceptance and after repair verification, or at any other time following the execution of initialization and training sequence of the ADSL system. ATN and SNR, as measured by the receivers at both the ATU-C and the ATU-R shall be externally accessible from the ATU-C, but they are not required to be continuously monitored.

11.2.5.1 Near-end test parameters

The following near-end test parameters are required at the ATU-C, and are optional at the ATU-R.

– *Attenuation (ATN):* An atn primitive is the difference in dB between transmitted and received signal power. Signal power in dBm is the sum of all active DMT subcarrier powers averaged over a 1 s period. An atn primitive is expressed as an integer number of dB ranging from a min. of x to a max. of y dB, x and y for further study so as to correspond to a sensible range of atn. An attenuation parameter is an instance of an atn primitive in response to an on-demand ATN test request;

– *Signal-to-noise ratio (SNR) margin:* An instance of an snr primitive (dB), in response to an on-demand SNR margin test request.

11.2.5.2 Far-end test parameters

The following far-end test parameters are required at the ATU-C (ATU-R is at the far-end), and are optional at the ATU-R (ATU-C is at the far-end):

– *Attenuation (ATN):* An instance of a far-end atn primitive (dB);

– *Signal-to-noise ratio (SNR) margin:* An instance of a far-end atn primitive (dB).

11.2.6 Performance monitoring functions

Near-end functions are required at the ATU-C, and are optional at the ATU-R. Far-end functions are required at the ATU-C (ATU-R is at the far-end), and are optional at the ATU-R (ATU-C is at the far-end).

11.2.6.1 Performance data storage

The following data registers are defined:

– A current 15 minute and a current 1 day register shall be provided for each near-end and for each far-end failure count and QOS parameter;
– A previous 15 minute and a previous 1 day register shall be provided for each near-end and for each far-end failure count and QOS parameter;
– A current and a previous register shall be provided for each near-end and for each far-end test parameter;
– A shared resource of 96 individual 15-minute registers per failure count and QOS parameter shall be assignable on-demand to a specific ADSL link. These registers shall not exceed about 10 % of the total dedicated failure count and QOS parameter memory resource requirements for all links over which this resource is shared.

NOTES
– Register sizes shall either accommodate maximum event counts or values, or have a minimum size of 16 bits;
– Register operation (e.g., pegging at the maximum value, resetting, setting of invalid data flag, etc.) shall comply with clause 9 of ANSI T1.231;
– Register invalid data flags shall be set if the ATUs are powered down during all or part of the accumulation interval (15 minutes or one day).

11.2.6.2 Performance data reporting

Performance data shall be reportable on demand (not scheduled) when queried by an operations entity.

11.3 Metallic testing

For further study

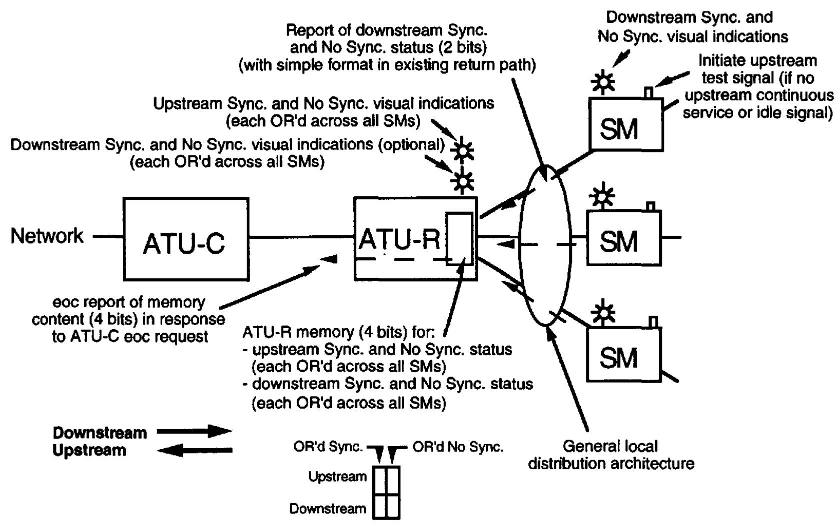
11.4 Out-of-service testing

For further study

11.5 Requirements to support OAM of the segment between ATU-R and SM

Requirements are expressed in terms of various indications for each direction of the segment between ATU-R and SM (downstream ATU-R to SM, and upstream SM to ATU-R). Downstream indications are also reported upstream from SMs to the ATU-R.

OAM of the ATU-R/ SM segment is null for SMs integrated in the ATU-R. For non-integrated SMs, requirements are as shown in figure 28.



NOTE – Visual indicators are shown as an example; not all implementations may provide them.

Figure 28 – OAM capabilities for the segment between ATU-R and the service module

11.5.1 SM requirements

The requirements for the service module (SM) are:

a) It shall detect separate downstream sync and no sync conditions. No sync is detected after 2.5 ± 0.5 seconds of persistent inability to acquire sync. Sync is detected after sync acquisition followed by 10 ± .5 seconds of persistent retention of sync;

b) It shall provide downstream sync and no sync indications, with corresponding interpretations. Exemplary interpretations are shown in table 33;

c) It shall report separate downstream sync and no sync status from SM to ATU-R (2 bits) in a simple format (for further study) on an existing return path (for further study) (e.g., control channel). For a single SM, the 2 bits shall have the interpretation specified in table 34. These interpretations are consistent with the indications in SM requirement (b) above;

Table 33 – Sync and no sync interpretation (downstream)

Sync	No sync	Interpretation
off	off	SM not powered
off	on	SM powered but not synchronized
on	off	SM synchronized
on	on	Invalid

Table 34 – Sync and no sync interpretation for single SM

Sync bit	No sync bit	Interpretation
0	0	SM not powered
0	1	SM powered but not synchronized
1	0	SM synchronized
1	1	Invalid

d) For services with upstream signals to which the ATU-R cannot continuously synchronize, the SM shall be able to send either an idle signal, or a locally-initiated test signal to the ATU-R for a (for further study) (e.g., 5) minute time-out period. The formats of these signals shall enable the ATU-R to synchronize to them in the same manner as for upstream service signals;

e) It shall be able to send a control channel (CC) acknowledge (ACK) message to the network in response to a CC query message from the network. Message formats are for further study.

11.5.2 ATU-R requirements

The requirements for the ATU-R are:

a) It shall detect separate upstream sync and no sync conditions (see requirement (d) below). No sync is detected after 2.5 ± 0.5 seconds of persistent inability to acquire sync. Sync is detected after sync acquisition followed by 10 ± 0.5 seconds of persistent retention of sync. Sync conditions from all SMs shall be logically OR'd into 1 bit, and no sync conditions from all SMs shall be logically OR'd into another bit;

b) It shall store the upstream OR'd sync. and OR'd no sync status (2 bits). For multiple SMs, the two bits shall have the interpretation specified in table 35;

Table 35 – Sync and no sync interpretation for multiple SMs

Sync bit	No sync bit	Interpretation
0	0	No SMs powered
0	1	At least 1 SM powered but not synchronized
1	0	At least 1 SM synchronized
1	1	Some SMs synchronized, others powered but not synchronized

c) It shall provide upstream OR'd sync and OR'd no sync indications (see requirement (d) below), consistent with the bit interpretations in ATU-R requirement (b) above. One example is:

Sync	No. Sync.	Interpretation
off	off	No SMs powered
off	on (e.g., red)	At least 1 SM powered but not synchronized
on (e.g., green)	off	At least 1 SM synchronized
on (e.g., green)	on (e.g., red)	Some SMs synchronized, others powered but not synchronized

d) Sync and no sync indications in ATU-R requirements (a) to (c) in this list apply to upstream service signals to which the ATU-R can continuously synchronize. Otherwise, an upstream idle signal, or the test signal in SM requirement (d) of 11.5.1 above shall be detected. With upstream idle signals, ATU-R detection, storage and indications and interpretations are as per ATU-R requirements (a) to (c) above. The same is true with the upstream test signal, during the time the test signal is being sent;

e) It shall detect separate downstream sync and no sync status reports from SMs, and logically OR each across all SMs, where OR'ing is as described in ATU-R requirement (a) in this list;

f) It shall store the downstream OR'd sync and OR'd no sync status (2 bits). For multiple SMs, the 2 bits shall have the same interpretation as for the upstream case in ATU-R requirement (b) in this list;

g) It shall provide downstream OR'd sync and OR'd no sync indications consistent with ATU-R requirement (c) in this list;

h) In response to an eoc request message from the ATU-C, it shall send a single eoc report of the upstream and downstream OR'd sync and OR'd no sync status to the ATU-C (4 bits).

11.5.3 ATU-C requirements

As per the ATU-R requirement 11.5.2(h), when requested by the network, the ATU-C shall be able to send an eoc message to retrieve the upstream and downstream OR'd sync and OR'd no sync status (4 bits), and to receive the corresponding eoc status report from the ATU-R.

12 Initialization

12.1 Overview

12.1.1 Basic functions of initialization

ADSL transceiver initialization is required in order for a physically connected ATU-R and ATU-C pair to establish a communications link. Establishment may be initiated by the ATU-C or the ATU-R as follows:

- An ATU-C, after power-up or loss of signal, and an optional self-test, may transmit activation tones (12.2) and await a response from the ATU-R (12.3.3). It shall make no more than two attempts; if no response is received it shall wait for an activation request from the ATU-R (12.3.1) or an instruction from the network to retry;

- An ATU-R, after power-up and an optional self-test, may repeatedly transmit activate request (12.3). If, however, the ATU-R receives C-TONE it shall remain silent for approximately one minute (12.3.2), unless it detects an activation signal (12.2.2).

In order to maximize the throughput and reliability of this link, ADSL transceivers shall determine certain relevant attributes of the connecting channel and establish transmission and processing characteristics suitable to that channel. The time line of figure 29 provides an overview of this process. In figure 29 each receiver can determine the relevant attributes of the channel through the transceiver training and channel analysis procedures. Certain processing and transmission characteristics can also be established at each receiver during this time. During the exchange process each receiver shares with its corresponding far-end transmitter certain transmission settings that it expects to see. Specifically, each receiver communicates to its far-end transmitter the number of bits and relative power levels to be used on each DMT sub-carrier, as well as any messages and final data rates information. For highest performance these settings shall be based on the results obtained through the transceiver training and channel analysis procedures.

ATU-C

Activation and acknowledgment (12.2)	**Transceiver training** (12.4)	**Channel analysis** (12.6)	**Exchange** (12.8)

ATU-R

Activation and acknowledgment (12.3)	**Transceiver training** (12.5)	**Channel analysis** (12.7)	**Exchange** (12.9)

time →

Figure 29 – Overview of initialization

Determination of channel attribute values and establishment of transmission characteristics requires that each transceiver produce, and appropriately respond to, a specific set of precisely-timed signals. This clause describes these initialization signals, along with the rules that determine the proper starting and ending time for each signal. This description is made through the definition of initialization states in which each transceiver will reside, and the definition of initialization signals that each transceiver will generate.
A state and the signal generated while in that state have the same name, which may sometimes, for clarity, be prefixed by "state" or "signal".

The sequence of generated downstream and upstream signals for a successful initialization procedure is shown by the time-lines of figures 30 – 33. The dashed arrow indicates that the change of state is caused by a successful reception of a specific signal. For example, in figure 32 ATU-R shall stay in state R-REVERB3 until it finishes receiving C-CRC2, at which point it shall move to R-SEGUE2 after an appropriate delay (see 12.7.2).

The description of a signal will consist of three parts:

- The first part is a description of the voltage waveform that the transmitter shall produce at its output when in the corresponding state;

The output voltage waveform of a given initialization signal is described using the DMT transmitter reference model shown in figure 2. Figure 2 is not a requirement or suggestion for building a DMT transmitter. Rather, it is a model for facilitating accurate and concise DMT signal waveform descriptions. In figure 2 X_k is DMT sub-carrier k (defined in the frequency domain), and x_k is the kth IDFT output sample (defined in the time domain). The DAC and analog processing block of figure 2 construct the continuous transmit voltage waveform corresponding to the discrete digital input samples. More precise specifications for this analog block arise indirectly from the analog transmit signal linearity and power spectral density specifications of 10.1. The use of figure 2 as a transmitter reference model allows all initialization signal waveforms to be described through the sub-carrier sequence X_{kn} required to produce that signal. Allowable differences in the characteristics of different digital to analog and analog processing blocks will produce somewhat different continuous-time voltage waveforms for the same initialization signal. However, a compliant transmitter will produce initialization signals whose underlying DMT sub-carrier sequences match exactly those provided in the signal descriptions of 12.2 to 12.9;

- The second is a statement of the required duration, expressed in DMT symbol periods, of the signal. This signal duration may be a constant or may depend upon the detected state of the far end transceiver. The duration of a single DMT symbol period depends on whether the cyclic prefix is being used; some initialization signals contain a cyclic prefix, and some do not. ATU-C signals up to and including C-SEGUE1 are transmitted without a cyclic prefix; those from C-RATES1 on are transmitted with a prefix. Similarly, ATU-R signals up to and including R-SEGUE1 do not use a prefix; those from R-REVERB3 on do. The duration of any signal in seconds is therefore the defined number of symbol periods times the duration of the symbol being used;

- The third part of a signal's description is a statement of the rule specifying the next state.

12.1.2 Transparency to methods of separating upstream and downstream signals.

Manufacturers may choose to implement this standard using either frequency-division-multiplexing (FDM) or echo canceling (EC) to separate upstream and downstream signals. The initialization procedure described here ensures compatibility between these different implementations by specifying all upstream and downstream control signals to be in the appropriate, but narrower, frequency bands that would be used by an FDM transceiver, and by defining a time period during which an EC transceiver can train its echo canceler.

12.1.3 Resetting during initialization and data transmission

If errors or malfunctions are detected or timeout limits are exceeded at various points in the initialization sequence, the ATU-C and ATU-R shall return to the initial states C-QUIET1 and R-ACT-REQ, respectively, for retraining. Furthermore, some errors detected during data transmission (i.e., after a successful initialization) may also require retraining. An example of an overall state diagram is shown in annex A, but the specific retraining procedures are for further study.

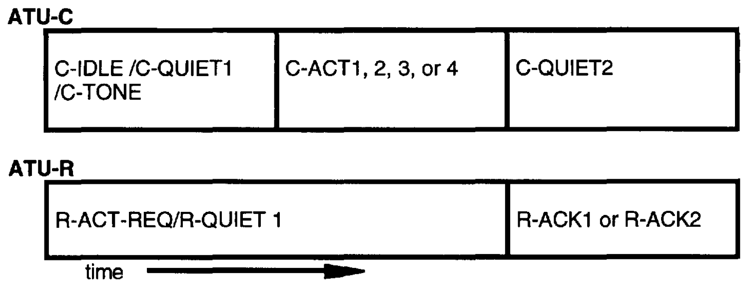


Figure 30 – Timing diagram of activation and acknowledgment (12.2-12.3)

12.2 Activation and acknowledgment – ATU-C

A host controller may be used to monitor the ATU-C activities and keep track of the state of the ATU-C if errors or malfunctions occur that require resetting to C-QUIET1, and retraining.

12.2.1 Pre-activate states

There are three mandatory pre-activation states at the ATU-C:

- C-QUIET1;
- C-IDLE;
- C-TONE.

The transitions between these and other vendor-optional states are shown in figure A.1, and described in annex A.

12.2.1.1 C-QUIET1

Upon power-up and after an optional self-test the ATU-C shall enter state C-QUIET1.

NOTE – QUIET and IDLE signals are defined as zero output voltage from the DAC of figure 2.

When the ATU-C is in C-QUIET1, either a command from the host controller or a successful detection of R-ACT-REQ (defined as detecting 128 consecutive symbols of active R-ACT-REQ signal followed by silent symbols) shall cause it to go to state C-ACT (see 12.2.2). To ensure full compatibility between FDM and EC systems, the ATU-C transmitter shall remain in state C-QUIET1 until the ATU-C receiver no longer detects the R-ACT-REQ signal. (i.e., detects the first symbol of R-QUIET1).

Alternatively, the host controller may command the ATU-C to enter C-IDLE.

12.2.1.2 C-IDLE

The ATU-C shall enter C-IDLE from C-QUIET1 in response to a host command. The difference between states C-QUIET1 and C-IDLE is that the ATU-C receiver reacts to R-ACT-REQ in C-QUIET1, but ignores it in C-IDLE.

If R-ACT-REQ is detected while in C-IDLE state, the host controller may elect to go to state C-TONE.

The ATU-C shall stay in C-IDLE indefinitely until the host controller issues the appropriate command to go to either state C-TONE (12.2.1.3), C-QUIET1 (12.2.1.1), C-ACT (12.2.2), or C-SELFTEST.

NOTE – C-SELFTEST is not defined herein; it is a vendor-option that does not affect compatibility.

12.2.1.3 C-TONE

The ATU-C shall transmit C-TONE to instruct the ATU-R not to transmit R-ACT-REQ. C-TONE is a single frequency sinusoid at $f_{C\text{-TONE}}$ = 310.5 kHz.

Referring to figure 2, C-TONE is defined as

$$X_k = \begin{cases} 0, k \neq 72, 0 \leq k \leq 256 \\ A_{C-TONE}, k = 72 \end{cases}$$

where $A_{C\text{-TONE}}$ shall be such that the transmit power level is –4 dBm (approximately –40 dBm/Hz over 4.3125 kHz) for the first 64 symbols, and –28 dBm for the second 64 symbols. This signal shall be transmitted for 128 consecutive symbols, and no cyclic prefix is used. C-IDLE immediately follows C-TONE.

12.2.2 C-Activate

To allow for inter-operability between FDM and EC systems, and among different vendors with different implementation of such systems, four activate signals, C-ACT1 to C-ACT4 are defined. These shall be used to distinguish different system requirements for loop timing and use of a pilot tone. These four signals are mutually exclusive; any given ATU-C shall transmit one and only one. Throughout the remainder of this document the generic term C-ACT will refer to the appropriate state and signal.

Loop timing is defined as the combination of the slaving of an ADC clock to the received signal (i.e., to the other transceiver's DAC clock), and tying the local DAC and ADC clocks together. Only one of the two transceivers can perform loop timing.

12.2.2.1 C-ACT1

The ATU-C shall transmit C-ACT1 to initiate a communication link to the ATU-R when the ATU-C will perform loop-timing, and the ATU-C cannot accept a pilot during R-QUIET3/R-PILOT1.

C-ACT1 is a single frequency sinusoid at $f_{C\text{-ACT1}}$ = 207 kHz. Referring to figure 2, C-ACT1 is defined by

$$X_k = \begin{cases} 0, k \neq 48, 0 \leq k \leq 256 \\ A_{C-ACT1}, k = 48 \end{cases}$$

where $A_{C\text{-ACT1}}$ shall be such that the transmit power level is –4 dBm (approximately –40 dBm/Hz over 4.3125 kHz) for the first 64 symbols, and –28 dBm for the second 64 symbols. This signal shall be transmitted for 128 consecutive symbols without a cyclic prefix. C-QUIET2 immediately follows C-ACT1.

12.2.2.2 C-ACT2

The ATU-C shall transmit C-ACT2 to initiate a communication link to the ATU-R when the ATU-C will not perform loop-timing, and the ATU-C cannot accept a pilot during R-QUIET3/R-PILOT1.

C-ACT2 is a single frequency sinusoid at $f_{C\text{-}ACT2}$ = 189.75 kHz, defined by

$$X_k = \begin{cases} 0, k \neq 44, 0 \leq k \leq 256 \\ A_{C-ACT2}, k = 44 \end{cases}$$

The level and duration of C-ACT2 shall be the same as those of C-ACT1. C-QUIET2 immediately follows C-ACT2.

12.2.2.3 C-ACT3

The ATU-C shall transmit C-ACT3 to initiate a communication link to the ATU-R when the ATU-C will perform loop-timing , and the ATU-C requests a pilot from the ATU-R during R-QUIET3/R-PILOT1. The decision whether to transmit R-PILOT1 is at the discretion of the vendor of the ATU-R.

C-ACT3 is a single frequency sinusoid at $f_{C\text{-}ACT3}$ = 224.25 kHz, defined by

$$X_k = \begin{cases} 0, k \neq 52, 0 \leq k \leq 256 \\ A_{C-ACT3}, k = 52 \end{cases}$$

The level and duration of C-ACT3 shall be the same as those of C-ACT1.

12.2.2.4 C-ACT4

The ATU-C shall transmit C-ACT4 to initiate a communication link to the ATU-R when the ATU-C will not perform loop-timing, and the ATU-C requests a pilot from the ATU-R during R-QUIET3/R-PILOT1. The decision whether to transmit R-PILOT1 is at the discretion of the vendor of the ATU-R.

C-ACT4 is a single frequency sinusoid at $f_{C\text{-}ACT4}$ = 258.75 kHz, defined by

$$X_k = \begin{cases} 0, k \neq 60, 0 \leq k \leq 256 \\ A_{C-ACT4}, k = 60 \end{cases}$$

The level and duration of C-ACT4 shall be the same as those of C-ACT1.

12.2.3 C-QUIET2

The purpose of C-QUIET2 is to allow the detection of R-ACK1 without the need to train the ATU-C echo canceller. The duration of C-QUIET2 is 128 symbols.

After C-QUIET2, ATU-C shall enter one of three states:

- *C-REVEILLE:* If the ATU-C detects R-ACK (see 12.3.3) it shall enter the state C-REVEILLE. Even if the ATU-C detects R-ACK in fewer than 128 symbols, the full duration of C-QUIET2 shall be maintained;
- *C-ACT:* If the ATU-C fails to detect R-ACK, and the state C-ACT has not been entered more than twice the ATU-C shall enter the state C-ACT. (A counter, which is reset upon entering C-QUIET1, should keep track of how many times ATU-C goes from C-QUIET2 and back to C-ACT);
- *C-QUIET1:* If the ATU-C does not detect R-ACK after returning twice to C-ACT it shall return to C-QUIET1.

12.3 Activation and acknowledgment – ATU-R

As in the ATU-C, a host controller may be used to monitor the ATU-R activities, and keep track of the state of the ATU-R if errors or malfunctions occur that require resetting to R-ACT-REQ.

12.3.1 R-ACT-REQ

R-ACT-REQ is used when it is desirable for the ATU-R to initiate a communication link to the ATU-C. One example is when a customer at ATU-R requests a service. R-ACT-REQ is transmitted after power-up and an optional successful self-test (see annex A). It is a single sinusoid at $f_{\text{R-ACT-REQ}}$ = 34.5 kHz, which, referring to figure 3, is defined by

$$X_k = \begin{cases} 0, k \neq 8, 0 \leq k \leq 32 \\ A_{\text{R-ACT-REQ}}, k = 8 \end{cases}$$

where $A_{\text{R-ACT-REQ}}$ shall be such that the transmit power level is –2 dBm (approximately –38 dBm/Hz over 4.3125 kHz) for the first 64 symbols and –22 dBm for the second 64 symbols, and $A_{\text{R-ACT-REQ}} = 0$ for the next 896 symbols. This signal is transmitted for 1024 consecutive symbols.

The ATU-R shall stay in R-ACT-REQ indefinitely (i.e., transmitting the single tone signal for 128 symbols, then shutting the signal off for 896 symbols, and then repeating the process) until either

- a successful detection of C-ACT signal from the ATU-C, in which case the ATU-R shall enter R-ACK as soon as the full duration of C-ACT signal has been detected;
- a successful detection of C-TONE signal from the ATU-C, in which case the ATU-R shall enter R-QUIET1.

12.3.2 R-QUIET1

The duration of R-QUIET1 depends upon whether the ATU-R detects C-ACT:

- if the ATU-R detects C-ACT it shall immediately enter R-ACK;
- if it does not, it shall remain quiet for 240,000 symbols (approximately 60 seconds) and then re-enter R-ACT-REQ.

12.3.3 R-Acknowledge

R-Acknowledge is transmitted by the ATU-R, as an acknowledgment of the detection of C-ACT, in order to continue initiating a communication link to the ATU-C. Three acknowledge signals are defined. The uses of R-ACK1 and R-ACK2 are defined; the use of R-ACK3 is for further study. Throughout the rest of this document the generic term R-ACK will refer to the appropriate state and signal.

12.3.3.1 R-ACK1

R-ACK1 signifies that the ATU-R cannot accept a pilot during C-QUIET3, C-QUIET4, or C-QUIET5. It is a single sinusoid at $f_{\text{R-ACK1}}$ = 43.125 kHz defined by

$$X_k = \begin{cases} 0, k \neq 10, 0 \leq k \leq 32 \\ A_{\text{R-ACK1}}, k = 10 \end{cases}$$

where $A_{\text{R-ACK1}}$ shall be such that the transmit power level is –2 dBm (approximately –38 dBm/Hz over 4.3125 kHz) for the first 64 symbols and –22 dBm for the second 64 symbols. This signal shall be transmitted for 128 consecutive symbols. R-QUIET2 follows immediately after R-ACK1.

12.3.3.2 R-ACK2

R-ACK2 signifies that the ATU-R requires a pilot during C-QUIET3, C-QUIET4, and C-QUIET5. It is a single sinusoid at $f_{\text{R-ACK2}}$ = 34.5 kHz defined by

$$X_k = \begin{cases} 0, k \neq 12, 0 \leq k \leq 32 \\ A_{\text{R-ACK2}}, k = 12 \end{cases}$$

The level and duration of R-ACK2 shall be the same as those of R-ACK1.

12.3.3.3 R-ACK3

R-ACK3 is reserved for future initialization options. It is a single sinusoid at $f_{\text{R-ACK3}}$ = 60.375 kHz defined by

$$X_k = \begin{cases} 0, k \neq 14, 0 \leq k \leq 32 \\ A_{\text{R-ACK3}}, k = 14 \end{cases}$$

The level and duration of R-ACK3 shall be the same as those of R-ACK1.

12.4 Transceiver training – ATU-C

This subclause and 12.5 define the signals transmitted during transceiver training by the ATU-C and ATU-R, respectively. Synchronization of the mutual training begins with the transmission of R-REVERB1 (see 12.5.2), and is maintained throughout training by both transceivers counting the number of symbols from that point on. Thus C-REVEILLE always coincides with R-QUIET2, C-QUIET5 or C-PILOT3 coincides with R-ECT, and so on.

ATU-C

C-REVEILLE	**C-QUIET3 or C-PILOT1**	**C-REVERB1**	**C-QUIET4 or C-PILOT2**	**C-ECT**	**C-REVERB2**	**C-QUIET5 or C-PILOT3**	**C-REVERB3**

ATU-R

R-QUIET2	**R-REVERB1**	**R-QUIET3 or R-PILOT 1**	**R-ECT**	**R-REVERB2**

time →

Figure 31 – Timing diagram of transceiver training (12.4-12.5)

12.4.1 C-REVEILLE

C-REVEILLE is a single frequency sinusoid at $f_{\text{C-REVEILLE}}$ = 241.5 kHz. Referring to figure 2, C-REVEILLE is defined by

$$X_k = \begin{cases} 0, k \neq 56, 0 \leq k \leq 256 \\ A_{C-REVEILLE}, k = 56 \end{cases}$$

where $A_{C\text{-REVEILLE}}$ shall be such that the transmit power level is –4 dBm for the first 64 symbols, and –28 dBm for the second 64 symbols. C-REVEILLE shall be used as an acknowledgment of the detection of R-ACK and as a transition to C-QUIET3 or C-PILOT1; it shall be transmitted for 128 consecutive symbols without cyclic prefix.

If the R-ACK1 was detected earlier the ATU-C shall enter C-QUIET3; if R-ACK2 was detected it shall enter C-PILOT1

12.4.2 C-QUIET3

During C-QUIET3, or C-PILOT1 as appropriate, the ATU-C shall measure the aggregate received upstream power on sub-carriers 7 – 18 of R-REVERB1, and thereby calculate a downstream PSD.

Upon detection of the first symbol of R-REVERB1 the ATU-C shall start a timer: this establishes synchronization of the subsequent transitions between states at ATU-C and ATU-R. After 512 symbols the ATU-C shall go to C-REVERB1. Thus the minimum duration of C-QUIET3 is 512 symbols, but it will exceed this by the round-trip propagation and signal-processing time plus the amount of time required by ATU-R to detect C-QUIET3 and respond by transmitting R-REVERB1 (see 12.5.2).

C-REVERB1 follows C-QUIET3.

12.4.3 C-PILOT1

C-PILOT1 is a single frequency sinusoid at $f_{C\text{-PILOT1}}$ = 276 kHz, defined by

$$X_k = \begin{cases} 0, k \neq 64, 0 \leq k \leq 256 \\ A_{C-PILOT1}, k = 64 \end{cases}$$

where $A_{C\text{-PILOT1}}$ shall be such that the transmit power level is –4 dBm.

The duration of C-PILOT1 shall be defined in the same way as that of C-QUIET3. C-REVERB1 follows C-PILOT1.

12.4.4 C-REVERB1

C-REVERB1 is a signal that allows the ATU-R receiver to adjust its automatic gain control (AGC) to an appropriate level. The data pattern used in C-REVERB1 shall be the pseudo-random downstream sequence (PRD), d_n for n = 1 to 512, defined in 6.9.3 and repeated here for convenience:

$d_n = 1$ for n = 1 to 9
$d_n = d_{n-4} \oplus d_{n-9}$ for n =10 to 512

The bits shall be used as follows: the first pair of bits (d_1 and d_2) is used for the dc and Nyquist sub-carriers (the power assigned to them is, of course, zero, so the bits are effectively ignored); then the first and second bits of subsequent pairs are used to define the X_i and Y_i. for i = 1 to 255 as follows:

d_{2i+1}, d_{2i+2}	Xi, Yi.
0 0	+ +
0 1	+ –
1 0	– +
1 1	– –

NOTES
1 The period of PRD is only 511 bits, so $d_{512} = d_1$.
2 The d_1 to d_9 are re-initialized for each symbol, so each symbol of C-REVERB1 uses the same data.

Bits 129 and 130, which modulate the pilot carrier (i = 64), shall be overwritten by {0,0}: generating the {+,+} constellation.

The nominal transmit PSD for C-REVERB1 is –40 dBm/Hz. If, however, the total upstream power measured on sub-carriers 7 – 18 is greater than 3 dBm, then the PSD for C-REVERB1 and all subsequent downstream signals shall be as follows:

Upstream received power	< 3	4	5	6	7	8	9	dBm
Max downstream PSD	–40	–42	–44	–46	–48	–50	–52	dBm/Hz

This chosen level shall become the reference level for all subsequent gain calculations.

The duration of C-REVERB1 is 512 (repeating) symbols without cyclic prefix. If the R-ACK1 was detected earlier the ATU-C shall then enter C-QUIET4; if R-ACK2 was detected it shall enter C-PILOT2.

12.4.5 C-QUIET4

The duration of C-QUIET4 is 3072 symbols. C-ECT follows C-QUIET4.

12.4.6 C-PILOT2

The C-PILOT2 signal is the same as C-PILOT1; the duration is 3072 symbols.

12.4.7 C-ECT

C-ECT is a vendor-defined signal that is used to train the echo canceller at ATU-C for EC implementations. Vendors of FDM versions have complete freedom to define their C-ECT signal. The duration of C-ECT, however, is fixed at 512 symbols. The receiver at ATU-R should ignore this signal. C-REVERB2 follows C-ECT.

NOTE – The level of the ADSL signal in the frequency band from 0 to about 10 kHz that leaks through the POTS low-pass filter is tightly limited (see 10.4). Therefore it is recommended that sub-carriers 1 – 4 not be used for C-ECT, or, at least, that they be transmitted at a much lower level.

12.4.8 C-REVERB2

C-REVERB2 is a signal that allows the ATU-R receiver to perform synchronization and to train any receiver equalizer. C-REVERB2 is the same as C-REVERB1 (see 12.4.3). The duration of C-REVERB2 is 1536 (repeating) symbols without cyclic prefix. If the R-ACK1 was detected earlier the ATU-C shall enter C-QUIET5; if R-ACK2 was detected it shall enter C-PILOT3

12.4.9 C-QUIET5

The duration of C-QUIET5 is 512 symbols. C-REVERB3 follows C-QUIET5.

12.4.10 C-PILOT3

C-PILOT3 is the same as C-PILOT1 (12.4.3).

12.4.11 C-REVERB3

C-REVERB3 is a second training signal, which allows the ATU-R receiver to perform or maintain synchronization and to further train any receiver equalizer. C-REVERB3 is the same as C-REVERB2 (see 12.4.6). The duration of C-REVERB3 is 1024 (repeating) symbols without cyclic prefix. This is the last segment of transceiver training. C-SEGUE1 follows immediately.

12.5 Transceiver training – ATU-R

12.5.1 R-QUIET2

The minimum duration of R-QUIET2 is 128 DMT symbols. The ATU-R shall progress to R-REVERB1 only after it has detected the whole of C-REVEILLE and any part of the following C-QUIET3 or C-PILOT1 that is needed for reliable detection. The time for detection of these signals shall not exceed 128 symbols each. If the ATU-R does not detect both signals within 128 symbols each it shall reset to R-ACT-REQ.

12.5.2 R-REVERB1

R-REVERB1 is used to allow the ATU-C to

- measure the upstream wideband power in order to adjust the ATU-C transmit power level;
- adjust its receiver gain control;
- synchronize its receiver and train its equalizer.

The data pattern used in R-REVERB1 shall be the pseudo-random upstream sequence PRU defined in 7.9.3 and repeated here for convenience:

$$d_n = 1 \qquad \text{for } n = 1 \text{ to } 6$$
$$d_n = d_{n-5} \oplus d_{n-6} \qquad \text{for } n = 7 \text{ to } 64$$

The bits are used as follows: the first pair of bits (d_1 and d_2) is used for the dc and Nyquist sub-carriers (the power assigned to them is, of course, zero, so the bits are effectively ignored); then the first and second bits of subsequent pairs are used to define the X_i and Y_i. for i = 1 to 31 as defined for C-REVERB1 in 12.4.4.

NOTES

1 The period of PRD is only 63 bits, so $d_{64} = d_1$.

2 The d_1 to d_6 are re-initialized for each symbol, so each symbol of R-REVERB1 uses the same data.

Bits 33 and 34, which modulate the pilot carrier (i = 16), shall be overwritten by {0,0}: generating the (+ +) constellation.

The nominal transmit PSD for R-REVERB1 and all subsequent upstream signals is –38 dBm/Hz.

R-REVERB1 is a periodic signal, without cyclic prefix, that is transmitted consecutively for 4096 symbols. The first 512 symbols coincide with C-QUIET3 or C-PILOT1 signal in time, the second 512 symbols coincide with C-REVERB1, and the last 3072 symbols coincide with C-QUIET4 or C-PILOT2.

If C-ACT1 or C-ACT2 was detected earlier the ATU-R shall enter R-QUIET3 immediately after R-REVERB1; if C-ACT3 or C-ACT4 was detected the ATU-R may enter R-PILOT1 or R-QUIET3 at the vendor's discretion.

12.5.3 R-QUIET3

The duration of R-QUIET3 is nominally 2048 symbols, of which the first 512 symbols coincide with C-ECT in time, and the next 1536 symbols coincide with C-REVERB2. The final symbol of R-QUIET3 may be shortened by any number of samples that is an integer multiple of four in order to accommodate transmitter to receiver frame alignment. R-ECT immediately follows R-QUIET3.

12.5.4 R-PILOT1

R-PILOT1 is a single frequency sinusoid at $f_{\text{R-PILOT1}}$ = 69 kHz, defined by

$$X_k = \begin{cases} 0, k \neq 16, 0 \leq k \leq 256 \\ A_{R-PILOT1}, k = 16 \end{cases}$$

where $A_{\text{R-PILOT1}}$ shall be such that the transmit power level is −2 dBm.

The nominal duration of R-PILOT1 is the same as that of R-QUIET3, but it may be shortened by any number of samples that is an integer multiple of four in order to accommodate transmitter to receiver frame alignment. R-ECT immediately follows R-PILOT1.

12.5.5 R-ECT

R-ECT, similar to C-ECT, is a vendor-defined signal that may be used to train an echo canceller at ATU-R. Vendors of FDM versions have absolute freedom to define the R-ECT signal. The duration of R-ECT, however, is fixed at 512 DMT symbols. The receiver at ATU-C should ignore this signal. R-REVERB2 follows R-ECT.

NOTE – The level of the ADSL signal in the frequency band from 0 to about 10 kHz that leaks through the POTS low-pass filter is tightly limited (see 10.4). Therefore it is recommended that sub-carriers 1 – 4 not be used for R-ECT, or, at least, that they be transmitted at a much lower level .

12.5.6 R-REVERB2

The signal R-REVERB2 is the same as R-REVERB1 (see 12.5.2); it can be used by ATU-C to perform timing recovery and receiver equalizer training.

NOTE – Some implementations of ATU-R transmitters may change the symbol timing between R-REVERB1 and R-REVERB2 (see 12.5.3 and 12.5.4); this would require a corresponding shift of any receiver timing acquired during R-REVERB1.

The duration of R-REVERB2 is 1024 symbols. This signal is the last segment of transceiver training. ATU-R then begins channel analysis, and starts transmitting R-SEGUE1.

ATU-C

C-SEGUE1	C-RATES1 , C-CRC1 , C-MSGS1, and C-CRC2	C-MEDLEY	C-REVERB4

ATU-R

R-SEGUE1	R-REVERB3	R-SEGUE2	R-RATES1, R-CRC1, R-MSGS1, and R-CRC2	R-MEDLEY	R-REVERB4

time →

Figure 32 – Timing diagram of channel analysis (12.6-12.7)

12.6 Channel analysis (ATU-C)

During channel analysis the synchronization between ATU-C and ATU-R may be broken during R-REVERB3, which has an indefinite duration; this potential timeout is described in 12.7.2. Furthermore, if during channel analysis any CRC check sum indicates an error in any of the control data, this shall trigger a reset to C-QUIET1.

12.6.1 C-SEGUE1

Except for the pilot tone, C-SEGUE1 is generated from a tone-by-tone 180 degree phase reversal of C-REVERB1 (i.e. + maps to –, and –maps to +, for each of the 4-QAM signal constellation). The duration of C-SEGUE1 is 10 (repeating) symbol periods. Following C-SEGUE1, ATU-C enters state C-RATES1.

12.6.2 C-RATES1

C-RATES1 is the first ATU-C signal for which a cyclic prefix (defined in 6.10) is used. The purpose of C-RATES1 is to transmit four options for data rates and formats to the ATU-R. Each option consists of three fields:

- B_F lists the number of bytes in the fast buffer for each of AS0, AS1, AS2, AS3, LS0, LS1, LS2, LS0 (upstream), LS1 (upstream), LS2 (upstream) channels, in that order; B_F has a total of 80 (= 10 × 8) bits. The first 8 bits of B_F specify the number of bytes in AS0, the second 8 bits specify the number of bytes in AS1, and so on. Each byte of B_F is transmitted with least significant bit first;

- B_I similarly lists the number of bytes in the interleaved buffer;

- $\{R_F, R_I, S, I, FS(\text{LS2})\}$ is a ten-byte quantity comprising
  - R_F, the number of parity bytes per symbol in the fast buffer (downstream);
  - R_I, the number of parity bytes per symbol in the interleave buffer (downstream);
  - S, the number of symbols per codeword (downstream);
  - I, the interleave depth (downstream) in codewords for the interleave buffer;
  - FS(LS2), the frame size (in bytes) of the bearer service transported in the LS2 channel;
  - the same five quantities $\{R_F, R_I, S, I, FS(\text{LS2})\}$ in the upstream direction (one-byte each, in that order).

The four options are transmitted in order of decreasing preference. C-RATES1 is preceded by a 4-byte prefix of [01010101 01010101 01010101 01010101]. Figure 33 summarizes C-RATES1 and R-RATES1 (see 12.7.4).

C-RATES1	Prefix	Option 1			Option 2			Option 3			Option 4		
		B_F	B_I	*RRSI*	B_F	B_I	*RRSI*	B_F	B_I	*RRSI*	B_F	B_I	*RRSI*
Number of bytes	4	10	10	10	10	10	10	10	10	10	10	10	10

R-RATES1	Prefix	Option 1			Option 2			Option 3			Option 4		
		B_F	B_I	*RRSI*	B_F	B_I	*RRSI*	B_F	B_I	*RRSI*	B_F	B_I	*RRSI*
Number of bytes	4	3	3	5	3	3	5	3	3	5	3	3	5

Figure 33 – C-RATES1 and R-RATES1 (12.6.2 and 12.7.4)

Only one bit of information is transmitted in each symbol of C-RATES1: a zero bit is encoded to one symbol of C-REVERB1 and a one bit is encoded to one symbol of C-SEGUE1. Since there are a total of 992 bits of C-RATES1 information, the duration of C-RATES1 is 992 symbols. The 992 bits are to be transmitted in the order shown in figure 33, with the least significant bit first. That is, the least significant bit of option 1, B_F, is to be transmitted during the 33rd symbol of C-RATES1, after the prefix. Following C-RATES1, the ATU-C shall enter state C-CRC1.

12.6.3 C-CRC1

C-CRC1 is a cyclic redundancy code for detection of errors in the reception of C-RATES1 at the ATU-R. The CRC bits are computed from the C-RATES1 bits using the equation:

$$c(\mathrm{D}) = a(\mathrm{D})\ \mathrm{D}^{16} \text{ modulo } \mathrm{g(D)},$$

where

$$a(\mathrm{D}) = a_0 \mathrm{D}^{959} \oplus a_1 \mathrm{D}^{958} \ldots \oplus a_{959}$$

is the message polynomial formed from the 960 bits of C-RATES1, with a_0 the least significant bit of the first byte of C-RATES1 (i.e., option 1 B_F);

$$\mathrm{g(D)} = \mathrm{D}^{16} \oplus \mathrm{D}^{12} \oplus \mathrm{D}^{5} \oplus 1$$

is the CRC generator polynomial, and

$$\mathrm{c(D)} = c_0\mathrm{D}^{15} \oplus c_1\mathrm{D}^{14} \ldots\ldots \oplus c_{14}\mathrm{D} \oplus c_{15}$$

is the CRC check polynomial.

The 16 bits $c_0 - c_{15}$ are transmitted (c_0 first and c_{15} last) in 16 symbol periods using the method described in 12.6.2. Following C-CRC1, the ATU-C shall enter state C-MSGS1.

12.6.4 C-MSGS1

C-MSGS1 transmits a 48-bit message signal to the ATU-R. This message includes vendor identification, ATU-C transmit power level used, trellis code option, echo canceller option, etc. The message, *m*, is defined by:

$$m = \{m_{47}, m_{30}, \ldots\ldots m_1, m_0\}$$

with m_0 being transmitted first. The message components are defined in the following sub-clauses, and their assigned positions within the composite message, *m*, are defined in table 36.

A total of 48 symbol periods are used to communicate the 48-bit message, using the encoding method described in 12.6.2. Following C-MSGS1, the ATU-C shall enter state C-CRC2.

Table 36 – Assignment of 48 bits of C-MSGS1

Suffix(ces) of m_i	Parameter
47 – 44	reserved for future use
43 – 28	vendor identification
27,26	reserved for future use
25 – 18	version number
17	constellation coding option
16	echo canceling option
15,14	reserved for future use
13,12	maximum possible transmit PSD
11,10,9	reserved for future use
8,7,6	transmit PSD during initialization
5,4	reserved for future use
3 – 0	maximum numbers of bits per sub-carrier supported

NOTES

1 All bits "reserved for future use" shall be set to 0 until defined.

2 Within the separate fields the least significant bits have the lowest subscripts.

12.6.4.1 Vendor identification – Bits 43 – 28

The vendor ID is binarily coded. Thirty-seven codes have so far been assigned; they are defined in annex D. Bits 47 – 44, the most significant bits (MSBs), may be used to identify more vendors in the future.

12.6.4.2 Version number – Bits 25 – 18

To facilitate upgrades in the future, six bits are reserved to allow any vendor to include a version number for each unit. When an ATU-C connects to an ATU-R with the same vendor ID, this may serve to simplify upgrades, diagnostics, maintenance, etc.

12.6.4.3 Constellation coding option – Bit 17

m_{17} = 0 shall indicate no trellis coding capability, m_{17} = 1 shall indicate trellis coding capability.

12.6.4.4 Echo cancellation option – Bit 16

m_{16} = 0 shall indicate no echo cancellation, m_{16} = 1 shall indicate echo cancellation.

12.6.4.5 Maximum possible transmit PSD – Bits 13,12

As defined in 6.13.3, the ATU-C may transmit, under some circumstances and in some frequency bands, at a PSD as high as –34 dBm/Hz. The ability to do this shall be signaled to the ATU-R so that it may calculate the optimum loading. The coding rules for m_{13}, m_{12} are

m_{13}	m_{12}	Max. PSD dBm/Hz
1	1	–34
1	0	–36
0	1	–38
0	0	–40

12.6.4.6 Transmit PSD during initialization – Bits 8,7,6

The ATU-C shall report the level of C-REVERB1 chosen as a result of the calculation described in 12.4.3. The encoding rules for m_8, m_7, m_6 are:

m_8	m_7	m_6	PSD dBm/Hz
1	1	1	–40
1	1	0	–42
1	0	1	–44
1	0	0	–46
0	1	1	–48
0	1	0	–50
0	0	1	–52

12.6.4.7 Maximum numbers of bits per sub-carrier supported – Bits 3 – 0

The $N_{downmax}$ (transmit) capability shall be encoded onto $\{m_3 - m_0\}$ with a conventional binary representation (e.g., 1101 = 13)

The maximum number of bits for the upstream data, N_{upmax}, that the ATU-C receiver can support need not be signaled to the ATU-R; it will be implicit in the bits and gains message, C-B&G, which is transmitted after channel analysis.

12.6.5 C-CRC2

C-CRC2 is a cyclic redundancy code for detection of errors in the reception of C-MSGS1 at the ATU-R. The CRC polynomial is generated in the same way as defined in 12.6.3. These 16 bits shall be transmitted in 16 symbol periods using the method described in 12.6.2. Following C-CRC2, the ATU-C shall enter state C-MEDLEY.

12.6.6 C-MEDLEY

C-MEDLEY is a wideband pseudo-random signal used for estimation at the ATU-R of the downstream SNR. The data to be transmitted shall be derived from the pseudo-random sequence, PRD, and modulated as defined in 6.9.3 and 12.4.4. In contrast to C-REVERB1, however, the data sequence continues from one symbol to the next (i.e., d_1 to d_9 are not re-initialized for each symbol); since PRD is of length 511, and 512 bits are used for each symbol, the sub-carrier vector for C-MEDLEY therefore changes from one symbol period to the next. The pilot sub-carrier is over-written by the (+,+) signal constellation.

C-MEDLEY shall be transmitted for 16384 symbol periods. Following C-MEDLEY the ATU-C shall enter the state C-REVERB4.

12.6.7 C-REVERB4

C-REVERB4 is similar to C-REVERB2 (see 12.4.6), the only difference being the addition of a cyclic prefix on every symbol. C-REVERB4 continues into the exchange procedure, and its duration is not fixed. The timeout features of C-REVERB4 are defined in 12.8.1

12.7 Channel analysis – ATU-R

During channel analysis there are two situations where the ATU-R will reset itself to R-ACT-REQ: a timeout and a detected error in the received control data. A timeout occurs if the time in R-REVERB3 exceeds the limit of 4000 symbols. Also, if any C-CRC checksum indicates there is an error in the received control data, then it shall trigger a reset to R-ACT-REQ.

12.7.1 R-SEGUE1

Except for the pilot tone, R-SEGUE1 is generated from a tone-by-tone 180 degree phase reversal of R-REVERB1 (i.e. + maps to –, and –maps to +, for each of the 4-QAM signal constellation). The duration of R-SEGUE1 is 10 symbol periods. Following R-SEGUE1 the ATU-R shall enter state R-REVERB3.

12.7.2 R-REVERB3

R-REVERB3 is similar to R-REVERB1 (see 12.5.2); the only difference is the addition of a cyclic prefix to every symbol. The duration of R-REVERB3 is not fixed but has a maximum of 4000 symbols. If C-SEGUE1 is not detected within 4000 symbols the ATU-R shall timeout and reset to R-ACT-REQ. After detection of C-SEGUE1 through C-CRC2, the ATU-R shall continue to send R-REVERB3 for 20 additional symbols before entering R-SEGUE2.

12.7.3 R-SEGUE2

The signal R-SEGUE2 is the same as R-SEGUE1 (see 12.7.1). The duration of R-SEGUE2 is 10 symbol periods. Following R-SEGUE2 the ATU-R shall enter state R-RATES1.

12.7.4 R-RATES1

The purpose of R-RATES1 for the upstream channel is the same as that of C-RATES1 for the downstream channel (see 12.6.2). Each option consists of three fields:

- B_F lists the number of bytes in the fast buffer for each of LS0, LS1, LS2, in that order; B_F has a total of 24 (= 3 × 8) bits. The first 8 bits of B_F specify the number of bytes in LS0, the second 8 bits specify the number of bytes in LS1, and so on. Each byte of B_F is transmitted with least significant bit first;

- B_I similarly lists the number of bytes in the interleaved buffer;

- {R_F, R_I, S, I, FS(LS2)} is a five-byte quantity comprising
  - R_F, the number of parity bytes per symbol in the fast buffer (upstream);
  - R_I, the number of parity bytes per symbol in the interleave buffer (upstream);
  - S, the number of symbols per codeword (upstream);
  - I, the interleave depth (upstream) in codewords for the interleave buffer;
  - FS(LS2), the frame size (in bytes) of the bearer service transported in the LS2 channel.

The four options are transmitted in order of decreasing preference. Figure 33 defines R-RATES1 as well as C-RATES1. For the present issue of the standard, ATU-C has control over all the data rates, so R-RATES1 is copied from the appropriate fields of C-RATES1.

Only one bit of information shall be transmitted during each symbol period of R-RATES1: a zero bit is encoded to one symbol of R-REVERB1 and a one bit is encoded to one symbol of R-SEGUE1. Since there are a total of 384 bits of RATES1 information, the length of R-RATES1 is 384 symbols. The 384 bits are to be transmitted in the order shown in figure 33, with the least significant bit first. That is, the least significant bit of option 1, B_F (see table 32), is to be transmitted during the 33rd symbol of R-RATES1, after the prefix. Following R-RATES1, the ATU-R shall enter state R-CRC1.

12.7.5 R-CRC1

R-CRC1 is a cyclic redundancy code intended for detection of an error in the reception of R-RATES1 at the ATU-C. The CRC polynomial c(D) and generator polynomial g(D) are the same as for C-CRC1 (see 12.6.3). The 16 bits c_0 to c_{15} are transmitted (c_0 first and c_{15} last) in 16 symbol periods using the same method as R-RATES1 (see 12.7.4). Following R-CRC1, the ATU-R shall enter state R-MSGS1.

12.7.6 R-MSGS1

R-MSGS1 transmits a 48-bit message signal to the ATU-C. This message includes vendor identification, trellis code option, echo canceller option, etc. The message, *m*, is defined by:

$$m = \{m_{47}, m_{30}, \ldots\ldots, m_1, m_0\}$$

with m_0, the least significant bit, being transmitted first. The message components are defined in the following subclauses, and their assigned positions within the composite message, *m*, are defined in table 37.

A total of 48 symbol periods shall be used to communicate the 48-bit message, using the encoding method described in 12.6.2 Following R-MSGS1, the ATU-R shall enter state R-CRC2.

Table 37 – Assignment of 48 bits of R-MSGS1

Suffix(ces) of m_i	Parameter
47 – 44	Reserved for future use
43 – 28	Vendor Identification
27,26	Reserved for future use
25 – 18	Version Number
17	Constellation coding option
16	Echo cancelling option
15 – 4	Reserved for future use
3 – 0	Maximum numbers of bits per sub-carrier supported
NOTES 1 All bits "reserved for future use" shall be set to 0 until defined. 2 Within the separate fields the least significant bits have the lowest subscripts.	

12.7.6.1 Vendor identification – Bits 43 – 28

The vendor ID is coded in binary as defined in 12.6.4.1

12.7.6.2 Version number – Bits 25 – 18

The version number is encoded as defined in 12.6.4.2

12.7.6.3 Trellis coding option – Bit 17

m_{17} = 0 shall indicate no trellis coding capability; m_{17} = shall 1 indicate trellis coding capability.

12.7.6.4 Echo cancellation option – Bit 16

m_{16} = 0 shall indicate no echo cancellation; m_{16} = 1 shall indicate echo cancellation.

12.7.6.5 Maximum numbers of bits per sub-carrier supported – Bits 3 – 0

The N_{upmax} (transmit) capability shall be encoded onto $\{m_3 - m_0\}$ with a conventional binary representation (e.g., 1101 = 13)

NOTE – The maximum number of bits for the downstream data, $N_{downmax}$, that the ATU-R receiver can support need not be signaled to the ATU-C; it will be implicit in the bits and gains message, R-B&G, which is transmitted after channel analysis.

12.7.7 R-CRC2

R-CRC2 is a cyclic redundancy code for detection of errors in the reception of R-MSGS1 at the ATU-C. The CRC polynomial is generated in exactly the same way as described in 12.6.3. These 16 bits are transmitted in 16 symbol periods using the method described in 12.7.4. Following R-CRC2, the ATU-R shall enter state R-MEDLEY.

12.7.8 R-MEDLEY

R-MEDLEY is a wideband pseudo-random signal used for estimation of the upstream SNR at the ATU-C. The data to be transmitted are derived from the pseudo-random sequence PRU defined in 12.5.2, continuing from one symbol to the next. Because the sequence is of length 63, and 64 bits are used for each symbol, the sub-carrier vector for R-MEDLEY changes from one symbol period to the next. The pilot sub-carrier is over-written by the (+,+) signal constellation. R-MEDLEY is transmitted for 16384 symbol periods. Following R-MEDLEY the ATU-R shall enter state R-REVERB4.

12.7.9 R-REVERB4

R-REVERB4 is the same as R-REVERB3 (see 12.7.2). The duration of R-REVERB4 is 128 symbols. This signal marks the end of channel analysis, and R-SEGUE3 immediately follows R-REVERB4.

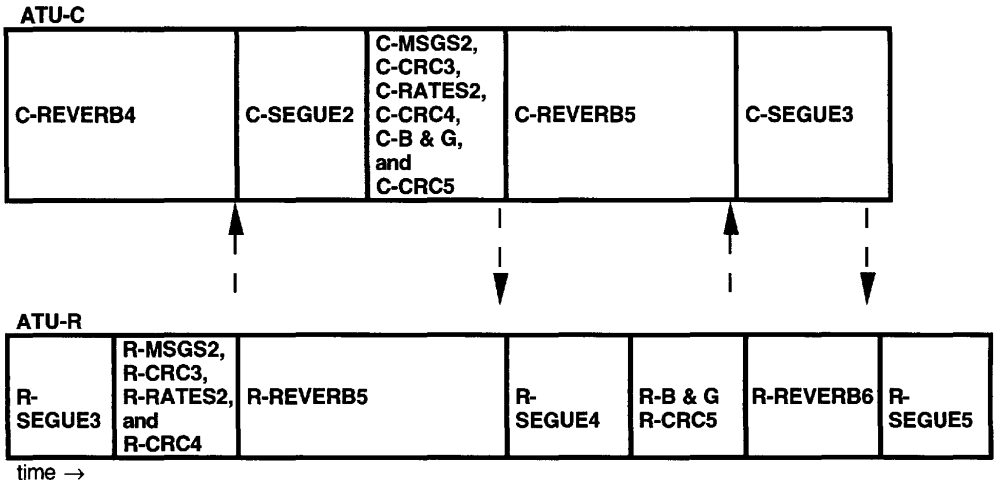


Figure 34 – Timing diagram of exchange (12.8-12.9)

12.8 Exchange – ATU-C

During exchange there are two events that shall cause the ATU-C to reset to C-QUIET1: timeouts and error detection by a CRC checksum. The exchange procedure is partly synchronized between ATU-C and ATU-R, and partly interactive. During the interactive part (C-REVERB4 and C-REVERB5) a timeout shall occur when the time in that state exceeds 4000 symbols.

12.8.1 C-REVERB4

If the ATU-C does not detect R-SEGUE3 within 4000 symbols, it shall timeout and reset to C-QUIET1. After detection of R-SEGUE3 and R-MSGS2, R-CRC3, R-RATES2, and R-CRC4, the ATU-C shall continue to transmit C-REVERB4 for another 80 symbols before progressing to state C-SEGUE2 (see 12.8.2).

12.8.2 C-SEGUE2

The signal C-SEGUE2 is the same as C-SEGUE1 (see 12.6.1). The duration of C-SEGUE2 is 10 symbol periods. Following C-SEGUE2 the ATU-C shall enter state C-MSGS2.

12.8.3 C-MSGS2

C-MSGS2 transmits a 32-bit message signal to the ATU-R. This message includes the total number of bits per symbol supported, the estimated upstream loop attenuation, and the performance margin with the selected rate option. The message, *m*, is defined by:

$$m = \{m_{31}, m_{30}, \ldots\ldots m_1, m_0\}$$

with m_0 being transmitted first. The message components are defined in the following sub-clauses, and their assigned positions within the composite message, *m*, are defined in table 38

Table 38 – Assignment of 32 bits of C-MSGS2

Suffix(ces) of m_i	Parameter
31 – 26	Estimated average loop attenuation
25 – 21	Reserved for future use
20 – 16	Performance margin with selected rate option
15 – 9	Reserved for future use
8 – 0	Total number of bits supported
NOTES 1 All bits "reserved for future use" shall be set to 0 until defined. 2 Within the separate fields the least significant bits have the lowest subscripts.	

A total of 4 symbol periods shall be used to communicate the 32 bit message, with 8 bits transmitted on each symbol. Two bits are encoded onto each of the sub-carriers numbered 43 through 46 using the 4QAM constellation labeling given in 6.9.3 (for the synchronization symbol) and 12.4.3 (for C-REVERB1). The same two bits are also encoded in the same way onto a set of backup carriers, namely, sub-carriers 37 through 40. The least significant byte of the message is transmitted in the first symbol of C-MSGS2, with the two least significant bits of each byte encoded onto carriers 43 and 37. In addition, the pilot, sub-carrier 64, shall be modulated with (+,+). Following C-MSGS2, the ATU-C shall enter state C-CRC3.

12.8.3.1 Estimated average upstream loop attenuation

During channel analysis the ATU-C estimates the upstream channel gain in preparation for computing the SNR for each tone; it shall also calculate the average loop attenuation. This attenuation, rounded to the nearest 0.5 dB, is then encoded into bits 31 – 26 of C-MSGS2 as the integer binary representation of twice the attenuation (e.g., if the average attenuation is 16.5 dB then $\{m_{31} - m_{26}\} = 100001$).

12.8.3.2 Performance margin with selected rate option

The ATU-C receiver shall calculate the performance margin for each of the rates options sent from the ATU-R during R-RATES1, and then select one of the options with a satisfactory margin. This margin (rounded to the nearest dB) is encoded into bits 20 – 16 of C-MSGS2 using a conventional binary representation (e.g., if the margin is 9 dB then $\{m_{20} - m_{16}\} = 01001$).

12.8.3.3 Total number of bits per symbol supported

The ATU-C receiver shall also calculate the maximum number of bits per symbol that the upstream channel can support with a performance margin of 6 dB at an error rate of 10^{-7}. This number is encoded into bits 8 – 0 using a conventional binary representation (e.g., if the maximum number of bits that can be supported is 127 (data rate = 508 kbit/s), $\{m_8 - m_0\} = 001111111$).

12.8.4 C-CRC3

C-CRC3 is a cyclic redundancy code for detection of errors in the reception of C-MSGS2 at the ATU-R. The CRC polynomial c(D) and generator polynomial g(D) are the same as for CRC1, as defined in 12.6.3. These bits are transmitted in 2 symbol periods using the method described in 12.8.3. Following C-CRC3, the ATU-C shall enter state C-RATES2.

12.8.5 C-RATES2

C-RATES2 is the reply to R-RATES1 (see 12.7.4). It combines the downstream rate information contained in R-RATES2 (in the form of one selected option) with the option number of the highest upstream data rate that can be supported based on the measured SNR of the upstream channel. It thus transmits the final decision on the rates that will be used in both directions. The length of C-RATES2 is equal to 8 bits, and the bit pattern for C-RATES2 is shown in table 39. Other bit patterns that are not specified in the table are reserved for future use. If none of the options requested during C-RATES1 and R-RATES1 can be implemented, ATU-C shall transmit the all-

options-fail code defined in table 39, and then return to C-QUIET1 for retraining. One symbol period is used to transmit these 8 bits using the method described in 12.8.3. Following C-RATES2, the ATU-C shall enter state C-CRC4.

Table 39 – Bit pattern for C-RATES2

(Downstream, upstream)	Bit pattern for C-RATES2 (MSB first) (note 1)
(option 1, option 1)	00010001
(option 1, option 2)	00010010
(option 1, option 3)	00010100
(option 1, option 4)	00011000
(option 2, option 1)	00100001
(option 2, option 2)	00100010
(option 2, option 3)	00100100
(option 2, option 4)	00101000
(option 3, option 1)	01000001
(option 3, option 2)	01000010
(option 3, option 3)	01000100
(option 3, option 4)	01001000
(option 4, option 1)	10000001
(option 4, option 2)	10000010
(option 4, option 3)	10000100
(option 4, option 4)	10001000
all options fail (Note 2)	00000000

NOTES

1 All other bit patterns that are not shown are reserved for future use.

2 If it is determined that none of the four options can be implemented with the connection the ATU-C shall return to C-QUIET1 for retraining.

12.8.6 C-CRC4

C-CRC4 is a cyclic redundancy code for detection of errors in the reception of C-RATES2 at the ATU-R. Its relation to C-RATES2 is the same as that of C-CRC3 to C-MSGS2. Following C-CRC4, the ATU-C shall enter state C-B&G.

12.8.7 C-B&G

C-B&G shall be used to transmit to the ATU-R the bits and gains , $\{b_1, g_1, b_2, g_2, \ldots.. b_{31}, g_{31},\}$, that are to be used on the upstream carriers. b_i indicates the number of bits to be coded by the ATU-R transmitter onto the ith upstream carrier; g_i indicates the scale factor, relative to the gain that was used for that carrier during the transmission of R-MEDLEY, that shall be applied to the ith upstream carrier. Because no bits or energy will be transmitted at dc or one-half the sampling rate, b_0, g_0, b_{32}, and g_{32} are all presumed to be zero and shall not transmitted.

Each b_i shall be represented as an unsigned 4-bit integer, with valid b_is lying in the range of zero to N_{upmax}, the maximum number of bits that the ATU-R is prepared to modulate onto any sub-carrier, which is communicated in R-MSGS1.

Each g_i shall be represented as an unsigned 12-bit fixed-point quantity, with the binary point assumed just to the right of the third most significant bit. For example, a g_i with binary representation (most significant bit listed first) 01000000 0000 would instruct the ATU-R to scale the constellation for carrier i, by a gain factor of 2, so that the power in that carrier shall be 6 dB higher than it was during R-MEDLEY.

For sub-carriers where no data are transmitted and the receiver will never allocate bits (e.g., out-of-band channels), both b_i and g_i shall be set to zero (0000 and 00000000 000, respectively). For sub-carriers where no data are currently to be transmitted, but the receiver may allocate bits later (e.g., as a result of an SNR improvement), the b_i shall be set to zero (0000) and the g_i to 1 (00100000 0000).

A total of 62 bytes of bits and gains information is to be transmitted during C-B&G, and a total of 62 symbol periods is required, using the method described in 12.8.2. Following C-B&G the ATU-C enters state C-CRC5.

12.8.8 C-CRC5

C-CRC5 is a cyclic redundancy code for detection of errors in the reception of C-B&G at the ATU-R. Its relation to C-B&G is the same as that of C-CRC3 to C-MSGS2. Following C-CRC5, the ATU-C shall enter state C-REVERB5.

12.8.9 C-REVERB5

C-REVERB5 is the same as C-REVERB4 (see 12.6.7). The duration of C-REVERB5 depends upon the state of the ATU-R and the internal processing of the ATU-C. The ATU-C shall transmit C-REVERB5 until it has received, checked the reliability of, and established the downstream bits and gains information contained in R-B&G. The ATU-C shall enter state C-SEGUE3 as soon as it is prepared to transmit according to the conditions specified in R-B&G.

12.8.10 C-SEGUE3

C-SEGUE3 is used to notify the ATU-R that the ATU-C is about to enter the steady-state state C-SHOWTIME. The signal C-SEGUE3 is the same as C-SEGUE1 (see 12.6.1). The duration of C-SEGUE3 is 10 symbol periods. Following C-SEGUE3 the ATU-C has completed initialization and enters state C-SHOWTIME.

12.9 Exchange – ATU-R

During exchange there are two cases where the ATU-R shall reset itself: timeouts and error detection by a CRC checksum. Both shall trigger a reset to R-ACT-REQ. The exchange procedure is partly synchronized between ATU-C and ATU-R, and partly interactive. During the interactive parts (R-REVERB5 and R-REVERB6) a timeout shall occur when the time in either state exceeds 4000 symbols.

12.9.1 R-SEGUE3

The signal R-SEGUE3 is the same as R-SEGUE1 (see 12.7.1). The duration of R-SEGUE3 is 10 symbol periods. Following R-SEGUE3 the ATU-R shall enter state R-MSGS2.

12.9.2 R-MSGS2

R-MSGS2 transmits a 32-bit message signal to the ATU-C. This message includes the total number of bits per symbol supported, the estimated upstream loop attenuation, and the performance margin with the selected rate option. The message, m, is defined by:

$$m = \{m_{31}, m_{30}, \ldots\ldots m_1, m_0\}$$

with m_0 being transmitted first. The message components are defined in the following sub-clauses, and their assigned positions within the composite message, m, are defined in table 40.

Table 40 – Assignment of 32 bits of R-MSGS2

Suffix(ces) of m_i	Parameter
31 – 25	Estimated average loop attenuation
24 – 21	Reserved for future use
20 – 16	Performance margin with selected rate option
15 – 12	Reserved for future use
11 – 0	Total number of bits supported
NOTES 1 All bits "reserved for future use" shall be set to 0 until defined. 2 Within the separate fields the least significant bits have the lowest subscripts.	

A total of 4 symbol periods shall be used to communicate the 32 bit message, with 8 bits transmitted on each symbol. Two bits are encoded onto each of the sub-carriers numbered 6 through 9 using the 4QAM constellation labeling given in 6.9.3 (for the synchronization symbol) and 12.4.3 (for C-REVERB1). The same two bits are also encoded in the same way onto a set of backup carriers, namely, sub-carriers 10 through 13. The least significant byte of the message is transmitted in the first symbol of R-MSGS2, with the two least significant bits of each byte encoded onto carriers 6 and 10. In addition, the pilot, sub-carrier 16, shall be modulated with (+,+). Following R-MSGS2, the ATU-R shall enter state R-CRC3.

12.9.2.1 Estimated average (upstream) loop attenuation

During channel analysis the ATU-R receiver estimates the downstream channel gain in preparation for computing the SNR for each tone; it shall also calculate the average loop attenuation. This attenuation, rounded to the nearest 0.5 dB, is then encoded into bits 31–25 of R-MSGS2 as the integer binary representation of twice the attenuation (e.g., if the average attenuation is 21.5 dB then $\{m_{31}, \ldots m_{25}\} = 0101011$).

12.9.2.2 Performance margin with selected rate option

The ATU-R receiver shall calculate the performance margin for each of the rates options sent from the ATU-C during C-RATES1, and then select one of the options with a satisfactory margin. This margin (rounded to the nearest dB) is encoded into bits 20 – 16 of R-MSGS2 using a conventional binary representation (e.g., if the margin is 9 dB then $\{m_{20}, \ldots m_{16}\} = 01001$).

12.9.2.3 Total number of bits per symbol supported

The ATU-R receiver shall also calculate the maximum number of bits per symbol that the downstream channel can support with a performance margin of 6 dB at an error rate of 10^{-7}. This number is encoded into bits 11–0 using a conventional binary representation (e.g., if the maximum number of bits that can be supported is 1724 (data rate = 6896 kbit/s), $\{m_{11}, \ldots m_0\} = 11010111100$).

12.9.3 R-CRC3

R-CRC3 is a cyclic redundancy code for detection of errors in the reception of R-MSGS2 at the ATU-C. The CRC polynomial c(D) and generator polynomial g(D) are as described in 12.6.3. These bits are transmitted in 2 symbol periods using the method described in 12.9.2. Following R-CRC3, the ATU-R shall enter state R-RATES2.

12.9.4 R-RATES2

R-RATES2 is the reply to C-RATES1 based on the results of the downstream channel analysis. Instead of listing the B_F, B_I as in C-RATES1, the ATU-R sends back only the option number of the highest data rate that can be supported based on the measured SNR of the downstream channel. As in C-RATES2, 4 bits are used for the option number. A total of 8 bits are used for R-RATES2, and the bit patterns are shown in table 41. Other bit patterns that are not specified in the table are reserved for future use. If none of the options requested during C-RATES1 can be implemented, ATU-R then returns to R-ACT-REQ for retraining. One symbol period is used to transmit these 8 bits using the method described in 12.9.2. Following R-RATES2, the ATU-R shall enter state R-CRC4.

Table 41 – Bit pattern for R-RATES2

Downstream	Bit pattern for R-RATES2 (MSB first) (note 1)
option 1	00010001
option 2	00100010
option 3	01000100
option 4	10001000
all options fail (note 2)	00000000

NOTES

1 All other bit patterns that are not shown are reserved for future use.

2 If it is determined that none of the four options can be implemented with the connection, the ATU-R shall return to R-ACT-REQ for retraining.

12.9.5 R-CRC4

R-CRC4 is a cyclic redundancy code for detection of errors in the reception of R-RATES2 at the ATU-C. Its relation to R-RATES2 is the same as that of R-CRC3 to R-MSGS2. Following R-CRC4, the ATU-R shall enter state R-REVERB5.

12.9.6 R-REVERB5

R-REVERB5 is the same as R-REVERB3 (see 12.7.2). The duration of R-REVERB5 depends upon the state of the ATU-C and the internal processing of the ATU-R, but has a maximum of 4000 symbols. The ATU-R shall transmit R-REVERB5 until it has received and checked the reliability of the upstream bits and gains information contained in C-B&G. After the ATU-R has received C-CRC5, it shall continue to transmit R-REVERB5 for another 64 symbols. It shall then enter R-SEGUE4. If it has not successfully detected all the control signals within 4000 symbols it shall timeout and reset to R-ACT-REQ.

12.9.7 R-SEGUE4

The purpose of R-SEGUE4 is to notify the ATU-C that the ATU-R is about to enter R-B&G. R-SEGUE4 is the same as R-SEGUE3 (see 12.9.1). The duration of R-SEGUE4 is 10 symbol periods. Following R-SEGUE4 the ATU-R enters state R-B&G.

12.9.8 R-B&G

The purpose of R-B&G is to transmit to the ATU-C the bits and gains information, $\{b_1, g_1, b_2, g_2, \ldots b_{255}, g_{255}\}$, to be used on the downstream sub-carriers. b_i indicates the number of bits to be coded by the ATU-C transmitter onto the ith downstream sub-carrier g_i indicates the scale factor that shall be applied to the ith downstream sub-carrier, relative to the gain that was used for that carrier during the transmission of C-MEDLEY. Because no bits or energy will be transmitted at DC or one-half the sampling rate, b_0, g_0, b_{256}, and g_{256} are all presumed to be zero, and are not transmitted.

Each b_i is represented as an unsigned 4-bit integer, with valid b_i lying in the range of zero to $N_{downmax}$, the maximum number of bits that the ATU-C is prepared to modulate onto any sub-carrier, which is communicated in C-MSGS1.

Each g_i is represented as an unsigned 12-bit fixed-point quantity, with the binary point assumed just to the right of the third most significant bit. For example, a g_i with binary representation (most significant bit listed first) 0100 0000 0000 would instruct the ATU-C to scale the constellation for carrier *i* by a gain factor of 2, so that the power in that carrier shall be 6 dB higher than it was during C-MEDLEY.

For sub-carriers where no data are transmitted and the receiver will never allocate bits (e.g., out-of-band channels), both b_i and g_i will be set to zero (0000 and 00000000 000, respectively). For sub-carriers where no data are currently to be transmitted, but the receiver may allocate bits later (e.g., as a result of an SNR improvement), the b_i will be set to zero (0000) and the g_i to 1 (00100000 0000)

A total of 510 bytes of bits and gains information is to be transmitted during R-B&G, so that a total of 510 symbol periods is required. The transmission format is the same as described in 12.9.2. Following R-B&G the ATU-R shall enter state R-CRC5.

12.9.9 R-CRC5

R-CRC5 is a cyclic redundancy code for detection of errors in the reception of R-B&G at the ATU-C. Its relation to R-B&G is the same as that of R-CRC3 to R-MSGS2. Following R-CRC5, the ATU-R shall enter state R-REVERB6.

12.9.10 R-REVERB6

R-REVERB6 is the same as R-REVERB3 (see 12.7.2). The duration of R-REVERB6 depends upon the state of the ATU-C and the internal processing of the ATU-R, but has a maximum of 4000 symbols. The ATU-R shall transmit R-REVERB6 until it has detected all ten symbols of C-SEGUE3; it shall then enter R-SEGUE5. If it has not successfully detected C-SEGUE3 within 4000 symbols it shall timeout and reset to R-ACT-REQ.

12.9.11 R-SEGUE5

The purpose of R-SEGUE5 is to notify the ATU-C that the ATU-R is about to enter the steady-state state R-SHOWTIME. R-SEGUE5 is identical to R-SEGUE3 (see 12.9.1). The duration of R-SEGUE5 is 10 symbol periods. Following R-SEGUE5 the ATU-R has completed initialization and shall enter state R-SHOWTIME.

13 On-line adaptation and reconfiguration

13.1 The ADSL overhead control (aoc) channel

As stated in 6.2 and 7.2, when any bearer data streams appear in the interleave buffer, then the aoc channel data is carried in the LEX byte, and the "synch" byte shall designate when the LEX byte contains aoc channel data and when it contains a data byte from the bearer data streams. When no bearer data streams are allocated to the interleave data buffer (i.e., all B_I (ASX) = 0 and all B_I (LSX) = 0 for the downstream case or all B_I (LSX) = 0 for the upstream case, respectively), then the "synch" byte carries the aoc channel data directly, because the LEX byte does not exist in the interleave buffer in this case.

13.1.1 aoc message header

The type and length of an aoc message is determined by a byte-length header. In particular, the aoc channel sends all binary zeros in the idle mode, and a valid aoc message always begins with a non-zero byte. Table 42 summarizes the current valid aoc message headers. For example, in the case of a bit swap, the aoc header "11111111" will be detected, and the next byte of aoc data shall determine whether the message is a bit swap request or a bit swap acknowledge (see 13.2). In the case when a standardized function, such as a bit swap, is requested but cannot be performed by either the ATU-C or the ATU-R for whatever the reason, an unable to comply message ("11110000") is issued. Future aoc headers can be added when new aoc messages/functions are identified. Also, a block of aoc header values ("1100xxxx") is set aside for vendor specific aoc messages.

Table 42 – aoc message headers

Value	Interpretation
00000000	Idle mode
00001111	Reconfiguration commands
1100xxxx	Reserved for vendor specific commands
11110000	Unable to comply
11111100	Extended bit swap request
11111111	Bit swap commands

13.1.2 aoc protocol

All aoc messages are transmitted 5 consecutive times for extra security. A transceiver unit shall only act on an aoc message if it has received three identical messages in a time period spanning 5 of that particular message. When a receiving unit detects an unrecognizable command, no action shall be taken by the receiving unit. The transmitting unit (the originating unit of the aoc command) is responsible for any time outs and/or local recovery schemes, when no acknowledgment to its request has been detected over a reasonable period of time. Individual vendors of ADSL transceivers may implement any recovery scheme(s) of their choice.

13.2 High-level on-line adaptation – Bit swapping

Bit swapping enables an ADSL system to change the number of bits assigned to a subcarrier, or change the transmit energy of a subcarrier without interrupting data flow.

Either ATU may initiate a bit swap; the swapping procedures in the upstream and downstream channels are independent, and may take place simultaneously.

13.2.1 Bit swap channel

The bit swap process uses the aoc channel, described in 13.1. All bit swap messages shall be repeated five consecutive times over this channel.

13.2.2 Superframe counting

The transceivers coordinate the bit swaps as follows:

- The ATU-C and ATU-R transmitters shall start their counters immediately after transmitting C-SEGUE3 and R-SEGUE5, respectively; this marks the transition between initialization and steady state operation;
- Each transmitter shall increment its counter after sending each ADSL superframe (see 6.2);
- Correspondingly, each receiver shall start its counter immediately after receiving C-SEGUE3 or R-SEGUE5, respectively, and then increment it after receiving each superframe.

Synchronization of the corresponding transmitter and receiver superframe counters is maintained using the synch symbol in the ADSL frame structure. Any form of restart that requires a transition from initialization to steady state shall reset the superframe counter.

13.2.3 Bit swap request

Message header	Message field 1 (16 bits)		Message field 2 (16 bits)		Message field 3 (16 bits)		Message field 4 (16 bits)	
11111111 (8 bits)	Command (8 bits)	Subchannel index (8bits)	Command (8 bits)	Subchannel index (8bits)	Command (8 bits)	Subchannel index (8bits)	Command (8 bits)	Subchann index (8bits)

Figure 35 – Format of the bit swap request message

The receiver shall initiate a bit swap by sending a bit swap request back to the transmitter via the aoc channel. This request tells the transmitter what subcarriers are to be modified. Figure 35 illustrates the format of the bit swap request message, which contains the following:

- an aoc message header consisting of 8 binary ones;

- message fields 1 – 4, each of which each consists of an eight bit command followed by a related eight-bit subchannel index. Valid eight-bit commands for the bit swap message shall be as shown in table 43. The eight-bit subchannel index is counted from low to high frequencies with the lowest frequency subcarrier having the number zero.

Table 43 – Bit swap request commands

Value	Interpretation
00000000	Do nothing
00000001	Increase the allocated number of bits by one.
00000010	Decrease the allocated number of bits by one.
00000011	Change the transmitted power by the factor +1 dB
00000100	Change the transmitted power by the factor +2 dB
00000101	Change the transmitted power by the factor +3 dB
00000110	Change the transmitted power by the factor –1 dB
00000111	Change the transmitted power by the factor –2 dB
00001xxx	Reserved for vendor specific commands

The bit swap request message (i.e., header and message fields) is transmitted five consecutive times.

13.2.4 Extended bit swap request

Because a single-bit sub-carrier is not allowed, an extended bit swap request containing 6 fields shall be used when decreasing the number of bits on a sub-carrier from 2 to 0, or when increasing the number of bits on a sub-carrier from 0 to 2. The format of this extended bit swap request is similar to that of the bit swap request (13.2.3), but the number of message fields is increased to 6, and, as shown in table 44, the message header is 11111100.

Table 44 – Extended bit swap request

Message Header (8 bits)	Message Field #1 (16 bits)		Message Field #2 (16 bits)		Message Field #3 (16 bits)		Message Field #4 (16 bits)		Message Field #5 (16 bits)		Message Field #6 (16 bits)	
11111100												

The extended bit swap request is transmitted 5 consecutive times

13.2.5 Bit swap acknowledge

Message header (8 bits) 11111111	Command (8 bits) 11111111	Bit swap superframe counter number (8 bits)

Figure 36 – Format of the bit swap acknowledge

The transmitter shall act on a bit swap request when it has received three identical bit swap request messages. The transmitter shall then send a bit swap acknowledge. Figure 36 shows the format of the bit swap acknowledge message, which contains the following:

- an aoc message header containing 8 binary ones;

- one message field that consists of eight binary ones followed by the eight bit superframe counter number, which indicates when the bit swap is to take place. In particular, the new bit and/or transmit energy table(s) shall take effect starting from the first frame (frame 0) of an ADSL superframe, after the specified superframe counter number has been reached. In other words, if the bit swap superframe counter number contained in the bit swap acknowledge message is *n*, then the new table(s) shall take effect starting from frame 0 of the (*n*+1)th ADSL superframe.

The bit swap acknowledge is transmitted five consecutive times.

13.2.6 Bit swap – Receiver

The receiver shall act on a bit swap request when it has received three identical bit swap acknowledge messages. The receiver shall then wait until the superframe counter equals the value specified in the bit swap acknowledge. Then, beginning with frame 0 of the next ADSL superframe the receiver shall

- change the bit assignment of the appropriate subcarriers, and perform tone re-ordering based on the new sub-carrier bit assignment;

- update applicable receiver parameters of the appropriate subcarriers to account for a change in their transmitted energy

13.2.7 Bit swap – Transmitter

After transmitting the bit swap acknowledge, the transmitter shall wait until the superframe counter equals the value specified in the bit swap acknowledge. Then, beginning with frame 0 of the next ADSL superframe, the transmitter shall

- change the bit assignment of the appropriate subcarriers, and perform tone re-ordering based on the new sub-carrier bit assignment;

- change the transmit energy in the appropriate subcarriers by the desired factor.

13.3 Changes to data rates and reconfiguration

Specification of changes to data rates and reconfiguration on demand is for further study.

14 Signaling requirements

ADSL supports both simplex and duplex bearer channels in a variety of configurations (see 5.1).

Bearer service is defined as the CI to CI service (e.g., 1.536 Mbit/s unrestricted digital information) that is selected and is carried over a particular bearer channel on an ADSL system. ADSL bearer channels may support a variety of bearer services.

Two methods of signaling protocols for controlling bearer service are recognized for ADSL:

- *In-band signaling:* This is defined as a signaling protocol controlling a bearer service carried over an ADSL bearer channel, where the signaling protocol is within the same ADSL bearer channel as the bearer service. For example, a data protocol stack, such as TCP/IP or OSI, may employ network layer and higher layer signaling protocols within a bearer service transported over ADSL. In-band signaling protocols are carried transparently, and are neither affected nor interpreted by the ADSL system;

- *Out-of-band signaling:* This is defined as a signaling protocol controlling a bearer service carried over an ADSL bearer channel, where the signaling protocol is carried in a different ADSL bearer channel than the bearer service. In this case, the ADSL C channel shall be used to carry the signaling protocol.

When the LS1 duplex channel is used to carry an ISDN BRA (2B+D+overhead) payload, the ISDN BRA multiplex is carried transparently. For the ISDN bearer services carried on the BRA, the signaling is within the BRA D channel and is neither affected nor interpreted by the ADSL system.

15 Loop plant, impairments, and testing

The methods in this clause test ADSL system transmission performance. These laboratory methods evaluate a system's ability to minimize digital bit errors caused by interference from:

- crosstalk coupling from other systems;
- background noise;
- impulse noise;
- POTS signaling.

These potential sources of impairment are simulated in a laboratory set-up that includes test loops, test sets, and interference injection equipment, as well as the test system itself. Figure 37 shows the general arrangement for testing.

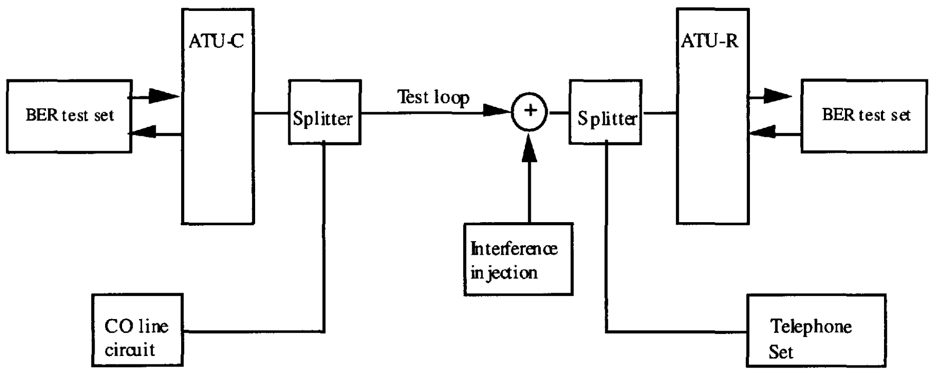


Figure 37 – Overview of test setup

The crosstalk and impulse noise interfering signals are simulations that are derived from a consideration of real loop conditions and measurements. The test procedure is to inject the interference into the test loops and measure the effect on system performance by a bit error test simultaneously run on the system information channels.

For crosstalk an initial, or reference, power level for the interference represents the expected worst case. If the interference power can be increased without exceeding a specified error threshold, the system has a positive performance margin. Performance margin, expressed in dB, is the difference between the interference level at which the error threshold is reached, and the reference (or 0 dB) level.

The specified error threshold with crosstalk interference is a BER of 10^{-7}; the minimum performance margin is 6 dB.

In the case of impulse noise, an increasing interference level is similarly applied up to the error threshold, and the estimated performance is computed from this information. Because the impulse noise characteristics of the loop plant are not completely understood, the estimation method is based on measured data from several sites. The estimated number of error-causing impulses is compared to a 0.14 % errored-seconds (ES) criterion. The test procedure makes separate determinations of crosstalk margins and impulse error thresholds, although a background crosstalk interference is applied during impulse tests.

The digital channel BER measurement shall be made while including impairments such as POTS signaling interference and crosstalk from other telephone lines. Tests shall be performed using signaling and alerting activities done with an electro-mechanical telephone set and either CO lines or a CO simulator.

15.1 Test loops

ADSL transmission at 1.536 Mbit/s is assessed in terms of performance against an objective of coverage over all copper loops without load coils conforming to Revised Resistance Design (RRD) rules as defined in Bellcore SR-TSV-002275. For test purposes, the RRD loops are represented by loops 7, 9 and 13 specified in 4.5.1 and figure 8 of ANSI T1.601. The primary cable constants are listed in tables G1 – G8 of ANSI T1.601. An additional loop (Loop #0) with a length of less than 10 feet is added to the T1.601 test loops.

ADSL transmission at 6.144 Mbit/s is assessed in terms of performance against an objective of coverage over loops that conform to Carrier Serving Area (CSA) design rules (a subset of RRD loops). For testing purposes, the CSA loops are represented by loops 4, 6, 7, and 8 shown in figures 13 and 14 of Committee T1 Technical Report No. 28.

For 10 or 24 disturber NEXT interference from T1 lines in adjacent binder groups, ADSL transmission is assessed with a mid-CSA loop.

The ADSL control channel and other duplex channels are evaluated with all test loops.

For convenience the configurations of the test loops are shown in figure 38, and their attenuation characteristics are given in annex E.

Table 45 describes a classification that ties together transport payload and loop range based on whether certain options available for the ATU transceivers are used. Category I (basic) describes loop ranges and transport payloads using basic transceivers with no options required. Category II (enhanced) describes loop ranges and transport payloads using options for trellis coding, transmit power boost, and echo cancellation.

Table 45 – ATU classification by category

Characteristics	Category I (basic)	Category II (optional)
Performance (see note 1)	see note 2	see note 2
Trellis option	off	on required
EC/FDM	optional	EC
Power boost	off	required capable

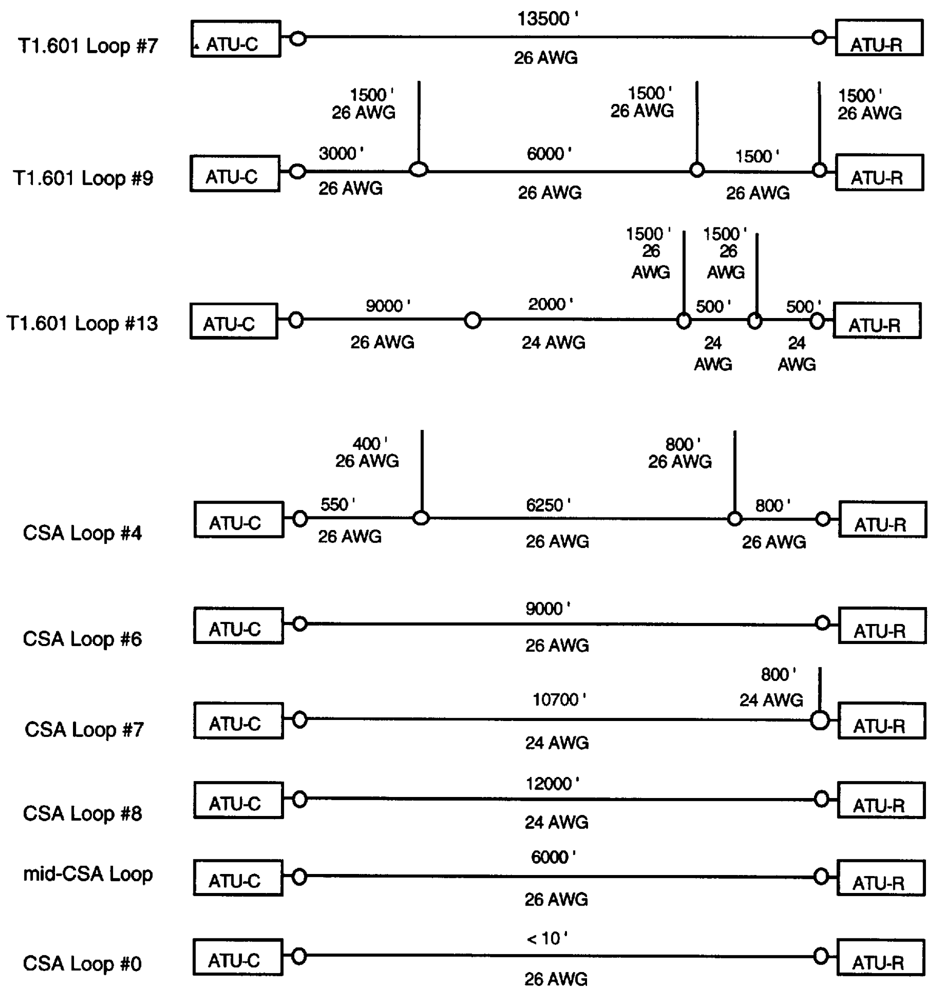
NOTES

1 Performance is defined as loop reach shown as a function of bit rate in table 46 and crosstalk as shown in tables 47–52.

2 The specific combinations of loops and rates shown in table 46, and crosstalk shown in tables 47 – 52 shall be tested for either category I or category II ATUs, as indicated.

Table 46 – Loop sets and maximum rates for category I and category II testing

Loop sets	ATU category	Maximum rate (kbit/s) Simplex	Duplex
T1.601 (7,13)	I	1544	16 + 160
CSA (4,6,7), Mid-CSA	I	6144	64 + 160
T1.601 (7,9,13)	II	1544	16 + 160
CSA (4,6,8), Mid-CSA	II	6144	64 + 576



NOTES

1 AWG = American Wire Gauge.
2 Distances are in feet ('): 100'

Figure 38 – Test loops

15.2 Impairments and their simulation in testing

15.2.1 Crosstalk

Crosstalk spectral compatibility is tested using simulations of the interference caused by coupling from other transmission systems sharing the same cable. Four combinations of white noise and NEXT from the following systems are used:

- DSL;
- HDSL;
- ADSL;
- T1 line (adjacent binder group).

For each of these the Power Spectral Density (PSD) of the transmitted signal and of the induced crosstalk is calculated for the appropriate number of disturbers and crosstalk model. The detailed analysis of the PSD and the model are provided in annex B.

The interferers used for the tests are

- 10 or 24 disturber DSL NEXT;
- 10 or 20 disturber HDSL NEXT;
- 10 or 24 disturber ADSL NEXT and FEXT;
- 4, 10 or 24 disturber T1 NEXT (adjacent binder group).

The resulting noise power spectra for these interferers are shown in annex B, where the derivation of the spectrum is described for each of these sources.

15.2.2 Impulse noise

There are two impulse waveforms defined for testing. These are reconstructions of actual recorded impulses observed in field tests, and represent the single most likely waveforms at specific sites. These waveforms are shown in figures 39 and 40 as approximations only. The two impulse waveforms for testing purposes are described in annex C with the amplitudes specified at 160 nanosecond intervals.

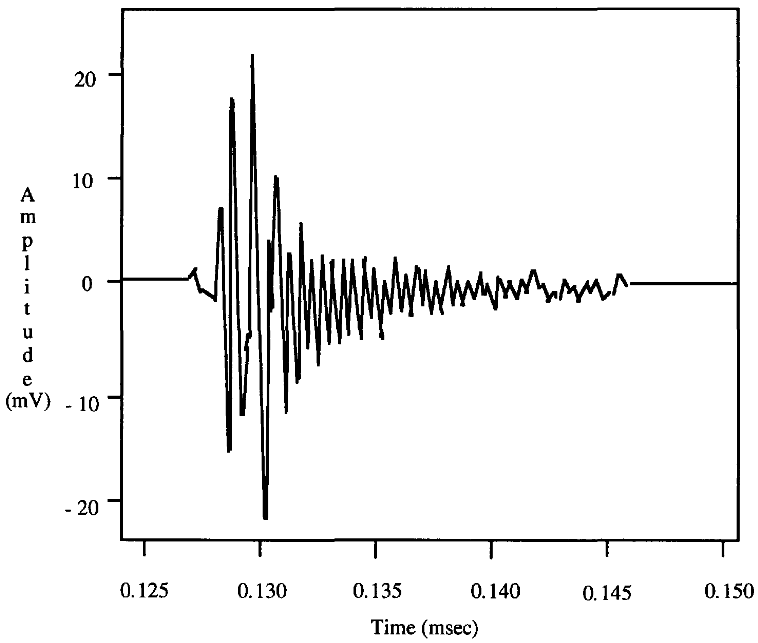


Figure 39 – Test impulse #1

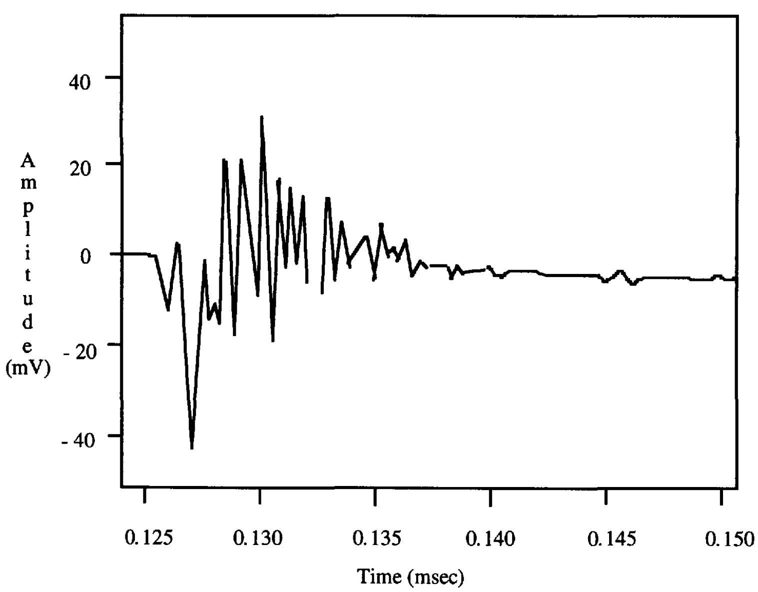


Figure 40 – Test impulse #2

15.3 Test procedures

15.3.1 Test setup

Figure 41 shows the test setup for measuring performance margins on ADSL systems. The test system consists of a central office transceiver (ATU-C), a remote end transceiver (ATU-R), and associated POTS splitters. The two transceivers are connected together by the test loop. Calibrated simulated crosstalk is injected through a high impedance network across the tip and ring of the loop at the input of one of the transceivers. Impulse noise from a waveform generator is similarly injected. Crosstalk and impulses are injected at the ATU-R for simplex channel tests, and at both the ATU-C and ATU-R for duplex channel tests.

Pseudo-random binary data from the transmitter of the bit error ratio (BER) test set is presented at the simplex channel input of the ATU-C, and the received clock and data outputs from the ATU-R are connected to the receiver of the same or a similar BER test set. The test set measures for BER or errored-seconds (ES), as needed. Similar error testing is done in both directions for the duplex channels at the rates needed for the particular system under test.

A telephone set is connected to the telephone jack of the splitter at the ATU-R end, and a working telephone line circuit is connected to the telephone jack on the splitter at the ATU-C end.

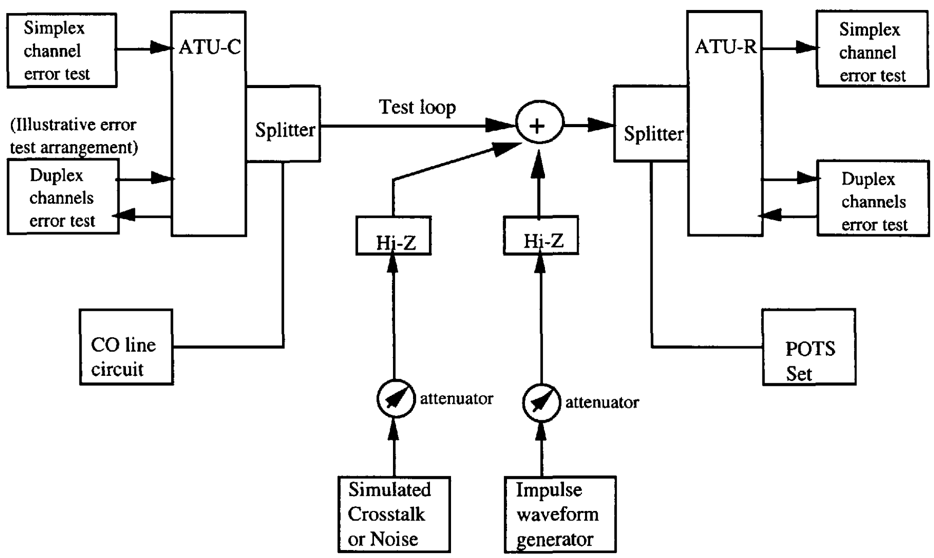


Figure 41 – Laboratory test setup for measuring performance margins

15.3.1.1 Crosstalk noise injection

Simulated crosstalk, XT (NEXT and/or FEXT) is introduced into the test loop at the ATU-R so as to achieve the appropriate voltage level without disturbing the impedance of the test loop or the transceiver. This is done with a balanced series feed of high impedance. One method for both test and calibration is shown in figure 42. The Thevenin impedance of all noise-coupling circuits connected to the test loop shall be greater than 4000 ohms.

The simulated XT should ideally have the power and spectral density defined by the equations for P_{NEXT} or P_{FEXT} in annex B. It is acknowledged, however, that if the method of generating the simulated XT is similar to that shown in figure 42, then its accuracy will depend on the design of the filter used to shape the white noise. Therefore a calculated XT PSD may be defined for which a tolerance on f_0 of +2 % is allowed at each null. Then the accuracy of the simulated XT shall be

within +1 dB of the calculated XT for all frequencies at which the calculated value is less than 45 dB below the peak value. The total power of the simulated XT shall be within +0.5 dB of the specified value using the same calibration termination.

The crest factor of the simulated XT shall be equal to or greater than 5.

The simulated XT PSD shall be verified using the calibration termination shown in figure 42 and a selective voltmeter or true RMS meter with a bandwidth of approximately 3 kHz. For DSL and HDSL crosstalk the circuit shall be calibrated for 1.3 dB less crosstalk than specified in annex B, in order to compensate for the use of 100 ohm terminations instead of 135 ohms.

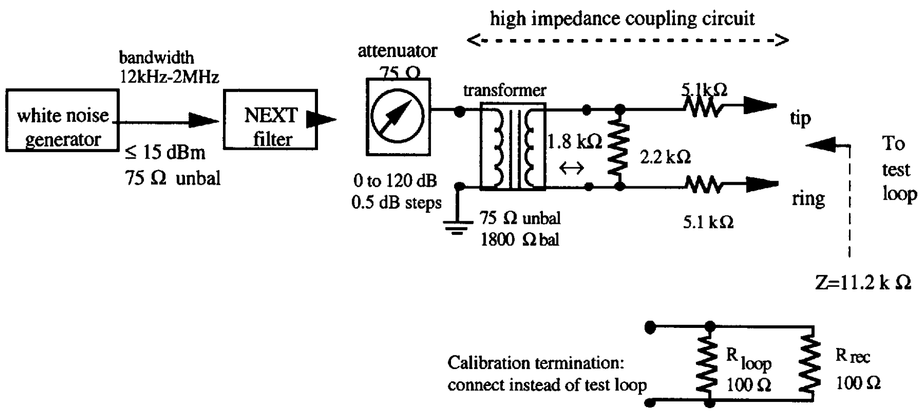


Figure 42 – High impedance crosstalk injection circuit

The characteristics of the white noise generator in figure 42 are crucial to the accuracy of the tests; consideration should be given to the following factors:

– *The probability distribution of the peak amplitude:* The noise shall be Gaussian within all frequency bands;

– *Crest factor:* This is an indication of the number of standard deviations to which the noise follows a Gaussian distribution; the required minimum is for further study, but is provisionally set at 5;

– *The frequency spectrum:* If the noise is generated using digital methods the sequence repetition rate will affect the correlation of the samples, and hence the frequency spectrum.

15.3.1.2 Impulse noise injection

The same coupling circuit as is used in 15.3.1.1 is used for impulse noise injection. The amplitude level of the impulses may be measured with an oscilloscope.

15.3.1.3 Error testing

The error test set(s) shall be capable of testing at all channel rates available in the test system (see clause 5). A test pattern of length $2^{23}-1$ shall be used.

15.3.2 Test conditions

15.3.2.1 Crosstalk interference

Tables 47 and 48 show the combinations of test loops, numbers of interferers, and data rates to be tested for category I and category II ATUs, respectively.

Table 47 – Crosstalk tests for category I

Test loops	Maximum simplex rate (Mbit/s)	Maximum duplex rate (kbit/s)	Margin (dB)	Crosstalk (note)			
				ADSL NEXT and FEXT	HDSL NEXT	DSL NEXT	T1 NEXT adj. binder
T1.601 (7,13)	1.544	16 + 160	6	–	–	24	–
CSA (4)	6.144	64 + 160	6	24	–	24	–
CSA (6)	6.144	64 + 160	6	–	20	–	–
CSA (7)	6.144	64 + 160	6	10	–	10	–
Mid-CSA loop	6.144	64 + 160	3	–	–	–	10

NOTE – The indicated interferers for each test are summed together with AWGN with PSD of – 140 dBm/Hz to form a composite power spectral density.

Table 48 – Crosstalk tests for category II

Test loops	Maximum simplex rate (Mbit/s)	Maximum duplex rate (kbit/s)	Margin (dB)	Crosstalk (note 1)			
				ADSL NEXT and FEXT	HDSL NEXT	DSL NEXT	T1 NEXT adj. binder
T1.601 (7,9,13)	1.544	16 + 160	6	–	–	24	–
CSA (4,6,8)	6.144	64 + 576	6	10	10	24	–
CSA (6)	6.144	64 + 576	0	–	–	–	4 (note 2)
Mid-CSA loop	6.144	64 + 576	6	–	–	10	24

NOTES

1 The indicated interferers for each test are summed together with AWGN with PSD of – 140 dBm/Hz to form a composite power spectral density.

2 In this case the higher transmit power option may be used.

15.3.2.2 Impulse test

Tables 49 and 50 show the combinations of test loops, interferers, and data rates to be tested.

Table 49 – Test loops, interferers, and data rates for impulse tests for category I

Test loops	Duplex rate (Mbit/s)	Simplex rate (kbit/s)	Interferers		
			Impulse 1	Impulse 2	crosstalk (note)
T1.601 (7,13)	1.544	16 + 160	y	y	y
CSA (4,6,7)	6.144	64 + 160	y	y	y
Mid-CSA (6 kft)	6.144	64 + 160	y	y	y

NOTE – The type of crosstalk interference applicable for each test is taken from the corresponding test in table 47. The total power of the applied interference shall be fixed at 4 dB below the reference level.

Table 50 – Test loops, interferers, and data rates for impulse tests for category II

Test loops	Duplex rate (Mbit/s)	Simplex rate (kbit/s)	Interferers		
			Impulse 1	Impulse 2	crosstalk (note)
T1.601 (7,9,13)	1.544	16 + 160	y	y	y
CSA (4,6,8)	6.144	64 + 576	y	y	y
Mid-CSA (6 kft)	6.144	64 + 576	y	y	y

NOTE – The type of crosstalk interference applicable for each test is taken from the corresponding test in table 48. The total power of the applied interference shall be fixed at 4 dB below the reference level.

15.3.2.3 POTS

The interference due to POTS service on the same line is generated by use of actual telephones and central office circuits connected in the normal way to the system under test. The following POTS signaling and alerting activities shall be performed:

- call phone at ATU-R and allow to ring 25 times;
- pick up ringing phone at ATU-R, 25 times;
- perform off-hook and on-hook activity on phone at ATU-R, 25 times;
- perform pulse and tone dialing.

Tables 51 and 52 show the combinations of test loops, interferers, and data rates to be tested for categories I and II.

Table 51 – Test loops, interferers, and data rates for POTS tests category I

Test loops	Maximum simplex rate	Maximum duplex rate	Interferers	
			POTS signaling	Crosstalk (note)
ANSI (7,13)	1.544 Mbit/s	16 + 160 kbit/s	y	y
CSA (4,6,7)	6.144 Mbit/s	64 + 160 kbit/s	y	y
Mid-CSA loop	6.144 Mbit/s	64 + 160 kbit/s	y	y
NOTE – The type of crosstalk interference applicable for each test is taken from the corresponding test in table 46. The total power of the applied interference shall be fixed 4 dB below the reference or 0 dB margin level.				

Table 52 – Test loops, interferers, and data rates for POTS tests category II

Test loops	Maximum simplex rate	Maximum duplex rate	Interferers	
			POTS signaling	Crosstalk (note)
ANSI (7,9,13)	1.544 Mbit/s	16 + 160 kbit/s	y	y
CSA (4,6,8)	6.144 Mbit/s	64 + 576 kbit/s	y	y
CSA (6)	6.144 Mbit/s	64 + 576 kbit/s	y	y
Mid-CSA loop	6.144 Mbit/s	64 + 576 kbit/s	y	y
NOTE – The type of crosstalk interference applicable for each test is taken from the corresponding test in table 48. The total power of the applied interference shall be at a fixed level of 4 dB down from the reference or 0 dB margin level.				

15.3.3 Test methods

With the test set-up as shown in figure 42, the test combinations described in 15.3.2 shall be tested as follows:

15.3.3.1 Crosstalk

Before testing, the ADSL units are trained with the crosstalk interference specified in 15.2.2 and 15.3.2.1 present. The simulated crosstalk power is injected at the appropriate reference level. The power levels given in 15.2.1 for each type of crosstalk are considered the 0 dB margin for that type and number of disturbers. For example, the 0 dB margin level for 24-disturber DSL crosstalk was –52.6 dBm. Margin measurements are made by changing, in whole dB steps, the power level of the crosstalk injected at the transceiver and monitoring the BER over the test loops. A tested system has positive margin for a given type of crosstalk on a given loop if the system was able to operate at a BER ≤ 1E-7 with injected crosstalk power greater than the 0 dB margin level.

The criteria for margin level determination shall include a check that the ADSL unit can train at the margin level.

The minimum testing times to determine BERs with 95% confidence are shown in table 53.

Table 53 – Minimum test time for crosstalk

Bit rate	Minimum test time
above 6 Mbit/s	100 seconds
1.544 Mbit/s to 6 Mbit/s	500 seconds
less than 1.544	20 minutes

15.3.3.2 Impulse noise

Before testing, the ADSL units are trained with the crosstalk interference specified in 15.3.2.2 present. The test procedure consists of injecting the selected impulse waveform at varying amplitude levels and random phase. At each level the impulse is applied 15 times with a spacing of at least one second while an error measurement is made on the ADSL channels. The amplitude (u_e) in millivolts at which half the impulses cause an error is determined for each waveform

Using the above amplitude determinations , the following equation gives the estimated probability that a second will be errored:

$$E = 0.0037\, P(u>u_e1) + 0.0208\, P(u>u_e2)$$

where: $P(u>u_e) = \dfrac{25}{u_e^2}$, for $5\text{ mV} \le u_e \le 40\text{ mV}$

$P(u>u_e) = \dfrac{0.625}{u_e}$, for $u_e > 40\text{ mV}$

u_e1 refers to waveform 1

u_e2 refers to waveform 2

The resulting value shall be less than the es criterion of 0.14%.

15.3.3.3 POTS interference

Before testing, the ADSL units are trained with the crosstalk interference specified in 15.3.2.3 present. Signaling disturbances are created through use of the CO line connected to the splitter at the ATU-C, and the telephone set connected to the telephone jack of the splitter at the ATU-R. During these activities, monitor the ADSL channels while noting any test conditions that cause errored seconds.

16 Physical characteristics

16.1 Wiring polarity integrity

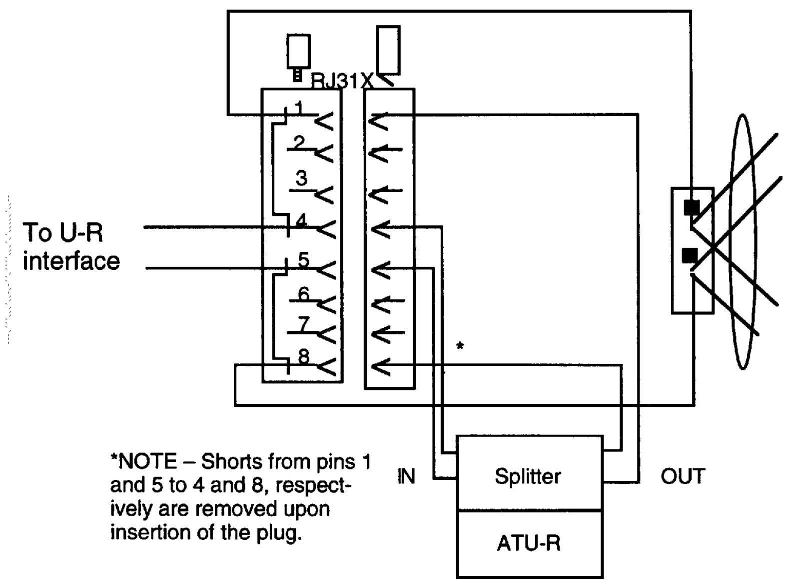
ADSL operation shall be independent of the polarity of the pair of wires connecting the ATU-C and ATU-R.

16.2 Connector

For single mountings, the connection of the POTS splitter to the existing CI wiring interface shall be as specified in table 54 and shown in figure 43 using an 8-pin plug and jack (RJ31X) equipped with shorting bars. In this configuration the cord connecting the POTS splitter and ATU-R unit shall be hard wired. The use of a separate POTS splitter physically separated from the ATU-R is not precluded by this standard. The layer 1 requirements for the ATU-R-to-splitter interface may be defined in a later issue of the standard. For multiple mountings, other connection arrangements may be appropriate.

Table 54 – Pin assignments for 8-position jack and plug (RJ31X) at U-R

Pin no.	Assignment for jack	Assignment for plug
1	Tip or ring to POTS distribution	Tip or ring to POTS splitter (out)
2	No connection	No connection
3	No connection	No connection
4	Tip or ring from network interface	Tip or ring to POTS splitter (in)
5	Tip or ring from network interface	Tip or ring to POTS splitter (in)
6	No connection	No connection
7	No connection	No connection
8	Tip or ring to POTS distribution	Tip or ring to POTS splitter (out)



*NOTE – Shorts from pins 1 and 5 to 4 and 8, respectively are removed upon insertion of the plug.

Figure 43 – Interface on the customer premises side of the U-R

16.3 Wiring requirements for a remotely located POTS splitter/ATU-R

It is recommended for a remotely located POTS splitter/ATU-R unit that the plug and jack arrangement specified in 16.2 be used. The connections between plug 1 and jack 2 are as specified in table 55, and illustrated in figure 44. The pin connections for plug 2 shall be as specified in table 54. In this configuration the cord connecting the POTS splitter and ATU-R unit shall be hard wired.

Table 55 – Pin assignments for 8-position jack and plug at remote location

Pin no.	Assignment for jack 2
1	From pin 1 of plug 1 to pin 1 of jack 2
2	No connection
3	No connection
4	From pin 4 of plug 1 to pin 4 of jack 2
5	From pin 5 of plug 1 to pin 5 of jack 2
6	No connection
7	No connection
8	From pin 8 of plug 1 to pin 8 of jack 2

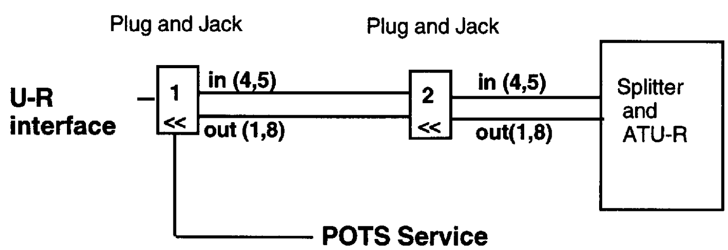


Figure 44 – Wiring for a remotely located POTS splitter/ATU-R

16.4 Maximum distance for a remotely located unit

The distance between plug and jack 1 and the remotely located POTS splitter and ATU-R unit shall not exceed (for further study) feet when the two pairs, (4,5) and (1,8), are in a common sheath.

17 Environmental conditions

17.1 Protection

Material referring to protection may be found in annex F of this standard.

17.2 Electromagnetic compatibility

Material referring to electromagnetic compatibility may be found in annex F of this standard.

Annex A
(normative)

ATU-C and ATU-R state diagrams

A.1 Introduction

This annex provides state diagrams for the ATU-C and ATU-R, some portions of which are mandatory to guarantee interworking between different manufacturers' units, and some portions of which are presented here as an example only – their functions may be required or desired, but the implementation is left to the vendor.

A.2 Definitions

The following terms and abbreviations are used in this annex. Where states or events have been defined elsewhere in this standard, the definitions are referenced here for convenience.

- C-ACT: See 12.2.2.
- C-TONE: See 12.2.1.3.
- R-ACT-REQ: See 12.3.1.
- R-ACK: See 12.3.3.
- lof-rs: Loss of ADSL frame synch/resync event. This event occurs when some algorithm, which may be vendor-specific, determines that a resync attempt is required. Note that this lof-rs event is probably (but not required to be) related to the sef (severely errored frame) defect defined for operations and maintenance (11.3).
- LOF: Loss of ADSL frame synchronization declared after sef time-out (near–end severely errored frame defect, defined in 11.3).
- LOS; Loss of received signal at "U" interface declared after los time-out (near–end loss of received signal defect, defined in 11.3).
- high BER: High bit error rate in received data: detected by thresholding #crc errors (near-end crc-8i and crc-8ni error anomalies, defined in 11.3) over some period of time.
- host control channel: An ATU-C configuration control channel from some host controller, such as an ACOT (ADSL Central Office Terminal), which controls one or more ATU-C line units. Note that this channel has no relationship or direct interworking with the 64 or 16 kbit/s "C" bearer channel, which is sometimes also called a control channel.
- reconfig1: A channelization reconfiguration that can be accomplished without resetting certain key portions of the data framing, transmitter, or receiver functions (clauses 6 and 7), and thus can be performed without disrupting channels that would not change as a result of the reconfiguration. For example, if four 1.536 Mbit/s simplex channels are currently active and are all allocated to the interleave data buffer, then a reconfiguration that requires two of them to remain active, and the other two to be replaced by a 3.088 Mbit/s channel would qualify as a reconfig1.
- reconfig2: A channelization reconfiguration that requires resetting of some key portion of the data framing, transmitter, or receiver functions (clauses 6 and 7), and which thus cannot be achieved without loss of some user data. This reconfiguration request will require a fast retrain. Examples are:
  - a change from the default bearer channel rates to optional rates, such as a request for a reconfiguration from a single 6.144 Mbit/s simplex bearer to a 6.312 Mbit/s simplex bearer, which requires a change in aggregate transmitted bit rate, FEC codeword size, and resetting the interleave/deinterleave functions;
  - if four 1.536 Mbit/s simplex channels are currently active and are all allocated to the interleave data buffer, then a reconfiguration that requires one or more of them to move to the fast data buffer would

require a fast retrain to allocate the extra AEX byte for the fast data buffer, to change the FEC codeword parameters of the interleaved data buffer, and to reset the interleave/deinterleave functions.

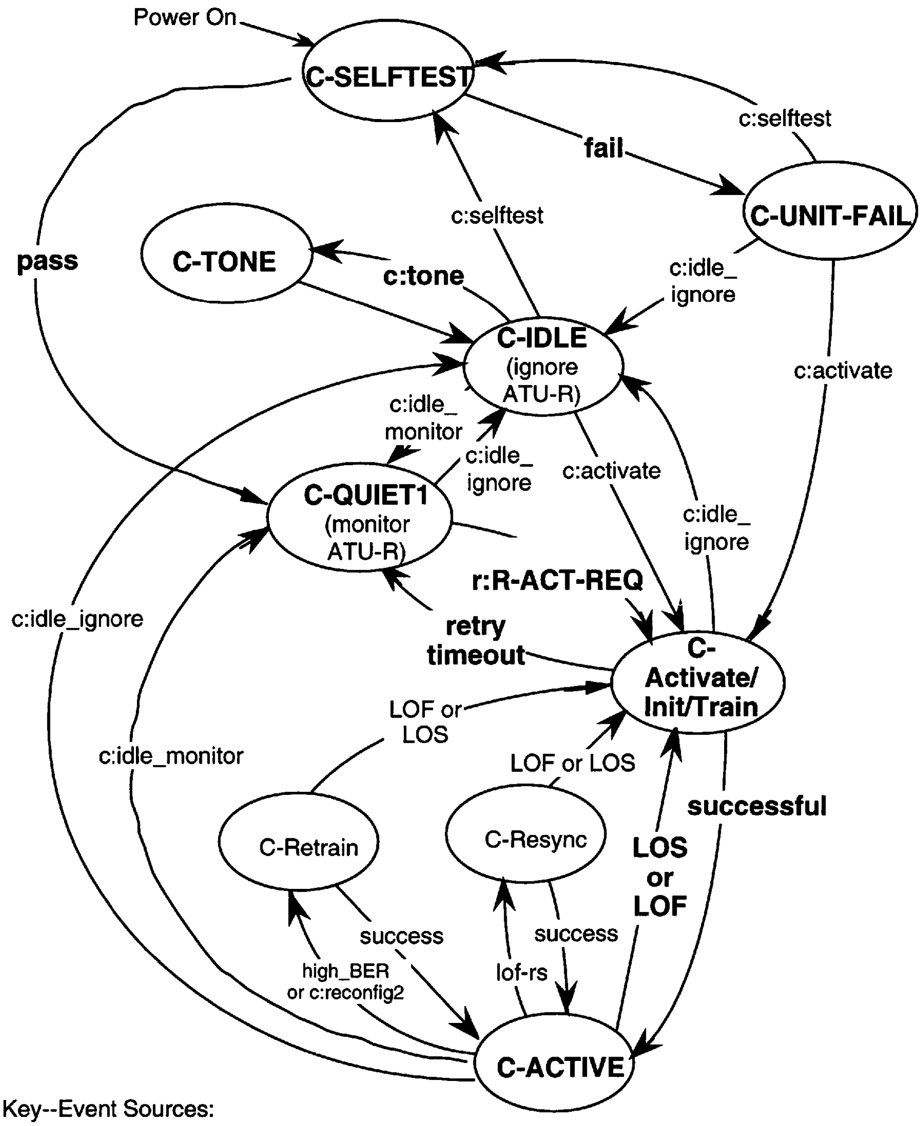
A.3 State diagrams

State diagrams are given in figure A.1 for the ATU-C, and in figure A.2 for the ATU-R. States are indicated by ovals, with the name of the state given within the oval. The states are defined in table A.1 for the ATU-C and in table A.2 for the ATU-R. Transitions between states are indicated by arrows, with the event causing the transition listed next to the arrow. For some events, the source of the event is indicated with letter(s) and a colon preceding the event name; a key to the source events is provided at the bottom of each figure. Mandatory states and events are indicated with **boldface type**; those states and events in normal face type are provided here as an example, with the form of their implementation left to the vendor.

In the state diagram for the ATU-C, a C-IDLE state would be desired to guarantee a quiet mode, which may be useful prior to provisioning, to allow certain tests (e.g., MLT), or to discontinue service. A selftest function is desirable, but it may be a vendor/customer option to define when selftest occurs (e.g., always at power-up or only under CO control), and which transition to take after successfully completing selftest (e.g., enter C-IDLE, or enter C-QUIET1, or enter C-Activate/Init/Train).

A variety of "host controller" commands (events preceded by "c:") are shown as non-mandatory in the ATU-C state diagram to provide example events and transitions between states. The way in which these events are implemented is left to the vendor, since many options are possible (e.g., separate host controller port on the ATU-C, switches or other front-panel controls, fixed options).

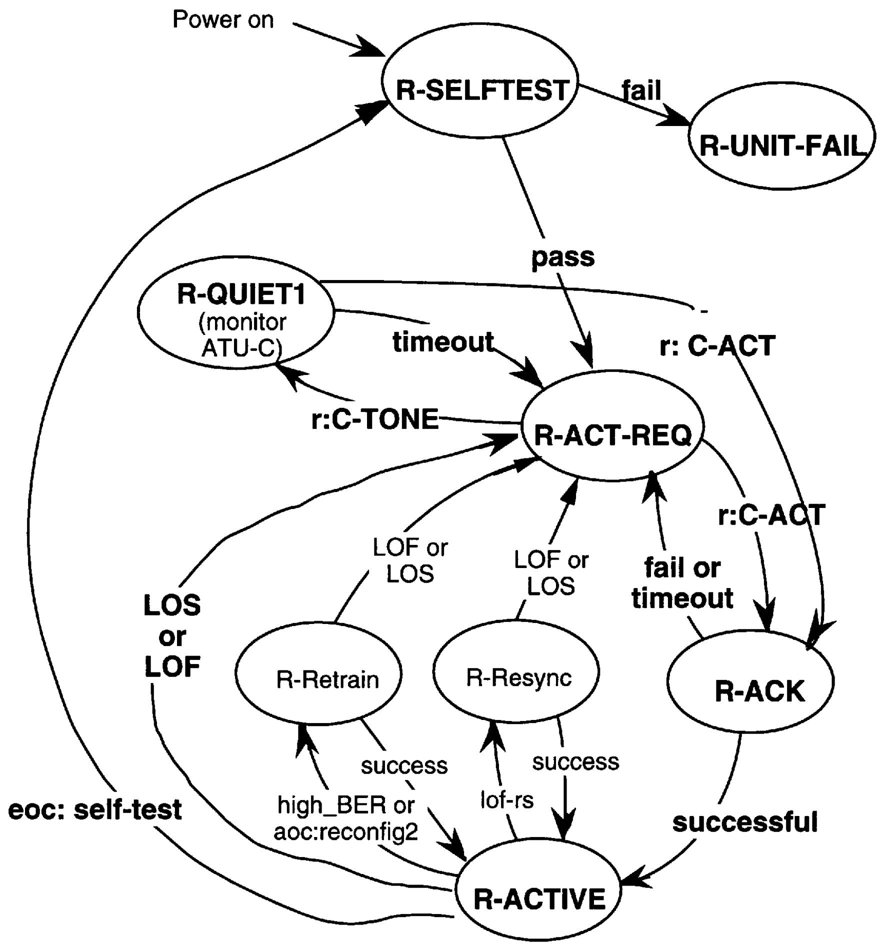
A "Retrain" state is shown as non-mandatory in both state diagrams (fast retrain is still under study). A "Resync" state is shown as non-mandatory in both state diagrams, to be left as a vendor option that may use vendor proprietary algorithms.



Key--Event Sources:
c:____ host controller command
r:____ received from ATU-R

State Definitions in table A.1
Terms defined in clause A.1

Figure A.1 – State diagram for the ATU-C



Key -- Event Sources:
r: received from ATU-C
eoc: embedded operations channel command
aoc: ADSL overhead control channel command

State Definitions in table A.2
Terms defined in clause A.1

Figure A.2 – State diagram for the ATU-R

Table A.1 – ATU-C state definitions

State name	Description
C-SELFTEST	Unit performs selftest. Transmitter and receiver off (quiet at U-C interface); no response to host control channel (e.g., ACOT)
C-UNIT-FAIL	(selftest failed) Monitor host control channel if possible (could allow ATU host controller to retrieve selftest results)
C-IDLE (12.2.2) (Idle; ignore ATU-R)	Transmitter and receiver off (no response to R-ACT-REQ). Monitor host control channel
C-TONE	Transmit C-TONE tone and transition back to C-IDLE
C-QUIET1 (12.2.1) (Idle; monitor ATU-R)	Transmitter off Receiver on, monitoring for R-ACT-REQ; if detected, transition to C-Activate/Init/Train state Monitor host control channel

C-Activate/Init/Train
(Starts with State C-ACT of 12.2; includes 12.2, 12.4, 12.6, 12.8)
	Initialize Train_Try_Counter
	while (--Train_Try_Counter >= 0)
	{ Transmit C-ACT (12.2.2)
	Start timer
	If receive R-ACK before timer expires
	proceed with initialization/training
	If successful, transition to C-ACTIVE
	}
	Transition to C-QUIET1

C-ACTIVE (Steady State Data Transmission; 6, 11.2, 11.3, 13)	Perform steady state bit pump functions (user data channels active) Allow bit swaps and non-intrusive reconfigurations (reconfig1) Monitor host control channel Monitor alarms, eoc, aoc If LOS or LOF event, transition to C-Activate/Init/Train
C-Resync (non-mandatory; vendor proprietary)	(State is entered when some algorithm, possibly based on loss of ADSL synch framing, determines that resync is required) Declare sef (defined in 11.3) – user data transmission has been disrupted If signal present (i.e., not los) Attempt to find synch pattern and realign (vendor proprietary) If successful, remove sef and transition to C-ACTIVE else time-out on sef, declare LOF event, transition to C-Activate/Init/Train else time-out on los, declare LOS event, transition to C-Activate/Init/Train

Table A.1 *(concluded)*

C-Retrain (fast retrain for further study)	(State can only be entered if received signal is still present and if ADSL frame synch is still maintained) Declare sef (defined in 11.3) – user data transmission has been disrupted If signal present (i.e., not los) Channel ID and bit allocation calculation Reset Data Framing and V-interface circuits If successful, remove sef and return to C-ACTIVE else time-out on sef, declare LOF event, transition to C-Activate/Init/Train else time-out on los, declare LOS event, transition to C-Activate/Init/Train

Table A.2 – ATU-R state definitions

State name	**Description**
R-SELFTEST	Unit performs selftest. Transmitter and receiver off (quiet at U-R interface) If selftest passes, transition to R-ACT-REQ else transition to R-UNIT-FAIL
R-UNIT-FAIL	(selftest failed – no exit from this state, except to cycle power)

R-ACT-REQ
(12.3.1)
	Receiver on, monitoring for C-ACT or C-TONE
	while (C-ACT not received AND C-TONE not received)
	{ Transmit R-ACT-REQ for 128 symbols (see 12.3.1)
	No transmission for 896 symbols
	}
	If (C-ACT was received) transition to R-Init/Train
	If (C-TONE was received) transition to R-QUIET1

R-QUIET1 (12.3.2) (Idle; monitor ATU-C)	Transmitter off; Receiver on, monitoring for C-ACT Start timer (60 seconds, see 12.3.2) At timeout transition to R-ACT-REQ
R-Init/Train (Starts with State R-ACK of 12.3; includes 12.3, 12.5, 12.7, 12.9)	Transmit R-ACK Proceed with Initialization and Training Sequence If successful, transition to R-ACTIVE else transition to R-ACT-REQ
R-ACTIVE (Steady State Data Transmission; 7, 11.2, 11.3, 13)	Perform steady state bit pump functions (user data channels active) Allow bit swaps and non-intrusive reconfigurations (reconfig1) Monitor alarms, eoc, aoc If LOS or LOF event, transition to R-ACT-REQ
R-Resync (non-mandatory; vendor proprietary)	(State is entered when some algorithm, probably based on loss of ADSL synch framing, determines that resync is required) Declare sef (defined in 11.3) – user data transmission has been disrupted If signal present (i.e., not los) Attempt to find synch pattern and realign (vendor proprietary) If successful, remove sef and transition to R-ACTIVE else time-out on sef, declare LOF event, transition to R-ACT-REQ else time-out on los, declare LOS event, transition to R-ACT-REQ

Table A.2 *(concluded)*

R-Retrain (fast retrain for further study)	(State can only be entered if received signal is still present and if ADSL frame synch is still maintained) Declare sef (defined in 11.3) – user data transmission has been disrupted Reset Data Framing and T-interface circuits If signal present (i.e., not los) Channel ID and bit allocation calculation If successful, remove sef and transition to R-ACTIVE else time-out on sef, declare LOF event, transition to R-ACT-REQ else time-out on los, declare LOS event, transition to R-ACT-REQ

Annex B
(normative)

Power spectral density of crosstalk disturbers

Crosstalk margin measurements were made for four types of disturbers, DSLs, HDSLs, T1s and ADSL lines. DSL, HDSL, and ADSL crosstalk is from pairs within the same binder group; T1 crosstalk is from pairs in an adjacent binder group.

B.1 Simulated DSL power spectral density and induced NEXT

The power spectral density (PSD) of Basic Access DSL disturbers is expressed as:

$$PSD_{\,DSL\text{-}Disturber} = K_{DSL} \times \frac{2}{f_o} \times \frac{\left[\sin\left(\frac{\pi f}{f_o}\right)\right]^2}{\left(\frac{\pi f}{f_o}\right)^2} \times \frac{1}{1+\left(\frac{f}{f_{3dB}}\right)^4}, \qquad f_{3dB} = 80\ kHz,\ 0 \le f < \infty$$

where $f_o = 80\ kHz$, $K_{DSL} = \frac{5}{9} \times \frac{V_p^2}{R}$, $V_p = 2.50$ Volts and R = 135 Ohms

This equation gives the single-sided PSD; that is, the integral of PSD, with respect to *f*, from 0 to infinity, gives the power in Watts. $PSD_{\text{DSL-Disturber}}$ is the PSD of an 80 kbaud 2B1Q signal with random equiprobable levels, with full-baud square-topped pulses and with 2nd order Butterworth filtering (f_{3dB} = 80 kHz).

The PSD of the DSL NEXT can be expressed as:

$$PSD_{\text{DSL-NEXT}} = PSD_{\text{DSL-Disturber}}\left(x_n f^{\frac{3}{2}}\right) \qquad 0 \le f < \infty,\ n = 1,\ 10,\ 24,\ 49$$

where $x_N = 0.882 \times 10^{-14} \times N^{0.6}$

The integration of $PSD_{\text{DSL-Disturber}}$ and $PSD_{\text{DSL-NEXT}}$ over various frequency ranges of interest are presented in table B.1.

Table B.1 – DSL transmit and induced NEXT power

Frequency Range	Transmit Power dBm	Next Power dBm 10 disturbers	NEXT Power dBm 24 disturbers
0 – 0.16 MHz	13.6	– 54.9	– 52.6
0 – 0.32 MHz	13.6	– 54.9	– 52.6
0 – 1.544 MHz	13.6	– 54.9	– 52.6

Figure B.1 shows the theoretical PSD of 24 Disturber DSL NEXT.

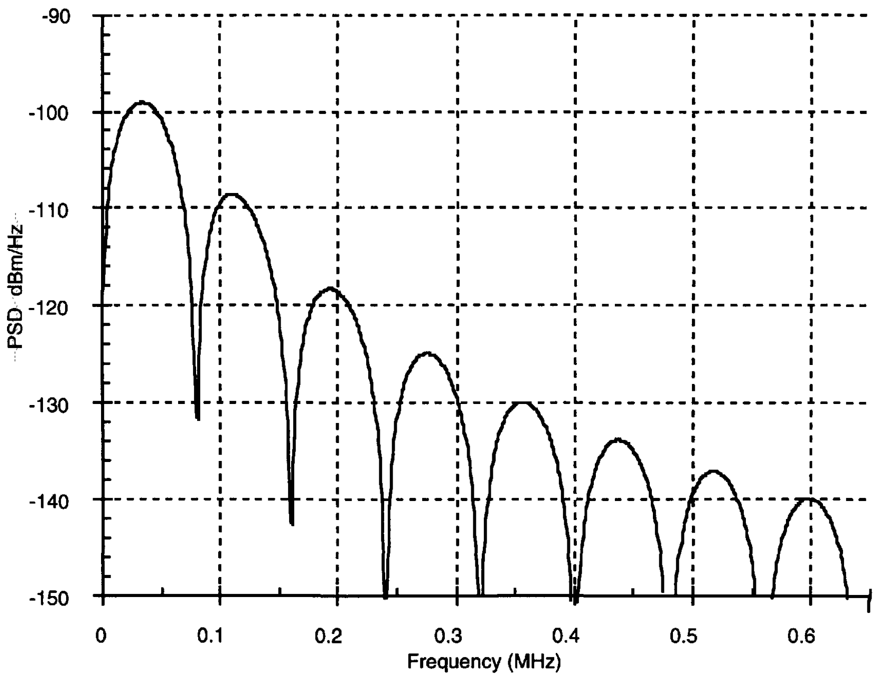


Figure B.1 – 24-disturber DSL NEXT

B.2 Simulated HDSL power spectral density and induced NEXT

The PSD of HDSL disturbers is expressed as:

$$PSD_{\text{HDSL-Disturber}} = K_{\text{HDSL}} \times \frac{2}{f_o} \times \frac{\left[\sin\left(\frac{\pi f}{f_o}\right)\right]^2}{\left(\frac{\pi f}{f_o}\right)^2} \times \frac{1}{1+\left(\frac{f}{f_{3dB}}\right)^8}, \qquad f_{3\text{dB}} = 196 \text{ kHz}, \ 0 \le f < \infty$$

$$\text{where } f_o = 392\text{kHz}, \ K_{\text{HDSL}} = \frac{5}{9} \times \frac{V_p^2}{R}, \ V_p = 2.70 \text{ Volts, and R} = 135 \text{ Ohms}$$

This equation gives the single-sided PSD; that is, the integral of PSD, with respect to f, from 0 to infinity, gives the power in Watts. $PSD_{\text{HDSL-Disturber}}$ is the PSD of a 392 kbaud 2B1Q signal with random equiprobable levels, with full-band square-topped pulses and with 4th order Butterworth filtering (f_{3dB} = 196 kHz).

The PSD of the HDSL NEXT can be expressed as:

$$PSD_{\text{HDSL-NEXT}} = PSD_{\text{HDSL-Disturber}} \left(x_n f^{\frac{3}{2}} \right), \qquad 0 \le f < \infty, \ n = 1, \ 10, \ 24, \ 49$$

where x_1, x_{10}, x_{24}, and x_{49} are defined in B.1

The integration of $PSD_{\text{HDSL-Disturber}}$ over various frequency ranges of interest is presented in table B.2 along with the induced NEXT power.

Table B.2 – HDSL transmit and induced NEXT power

Frequency range	Transit power dBm	NEXT Power 10 disturbers dBm	NEXT Power 20 disturbers dBm
0 – 0.196 MHz	13.4	– 46.9	– 45.1
0 – 0.392 MHz	13.6	– 46.3	– 44.5
0 – 0.784 MHz	13.6	– 46.3	– 44.5
0 – 1.544 MHz	13.6	– 46.3	– 44.5
0 – 1.568 MHz	13.6	– 46.3	– 44.5

Figure B.2. shows the theoretical PSD of 10-Disturber HDSL NEXT.

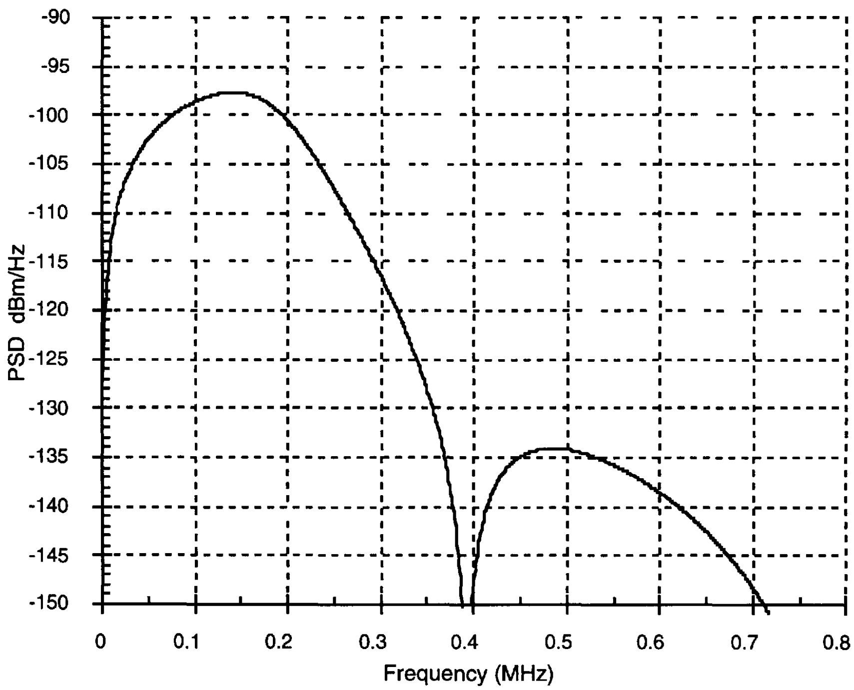


Figure B.2 – 10-disturber HDSL NEXT

B.3 Simulated T1 line power spectral density and induced NEXT

The PSD of the T1 line disturber is assumed to be the 50% duty-cycle random Alternate Mark Inversion (AMI) code at 1.544 Mbit/s. The single-sided PSD has the following expression:

$$PSD_{T1-Disturber} = \frac{V_P^2}{R_L} \times \frac{2}{f_o} \left[\frac{\sin\left(\frac{\pi f}{f_o}\right)}{\left(\frac{\pi f}{f_o}\right)} \right]^2 \sin^2\left(\frac{\pi f}{2 f_o}\right) \times \frac{1}{1+\left(\frac{f}{f_{3dB}}\right)^6} \times \frac{f^2}{f^2 + f_3 dB^2}, \qquad 0 \le f < \infty$$

The total power of the transmit T1 signal is computed by:

$$P_{T1-total} = \frac{1}{4} \frac{V_p^2}{R_L}$$

It is assumed that the transmitted pulse passes through a low-pass shaping filter. The shaping filter is chosen as a third order low-pass Butterworth filter with 3 dB point at 3.0 MHz. The filter magnitude squared transfer function is:

$$\left| H_{shaping}(f) \right|^2 = \frac{1}{1+\left(\frac{f}{f_{3dB}}\right)^6}$$

In addition, the coupling transformer is modeled as a high-pass filter with 3 dB point at 40 kHz as:

$$\left| H_{Transformer}(f) \right|^2 = \frac{f^2}{f^2 + f_{3\mathrm{dB}}{}^2}$$

Furthermore, it is assumed that V_p = 3.6 Volts, R_L = 100 Ohms, and f_o = 1.544 MHz.

The PSD of the T1 NEXT can be expressed as:

$$PSD_{\mathrm{T1-NEXT}} = PSD_{\mathrm{T1-Disturber}} \left(x_n f^{\frac{3}{2}} \right), \qquad 0 \le f < \infty,\ n = 4,\ 10,\ 24$$

where x_1, x_{10}, , and x_{24}, are defined in B.1

The T1 transmit and induced NEXT powers using n-crosstalk models (X_n) are presented in table B.3, and the PSDs of 4, 10, and 24 T1 NEXT disturbers are shown in figure B.3.

Table B.3 – T1 transmit and induced NEXT power with shaping and coupling transformer

Frequency Range	**Transmit Power** dBm	**NEXT Power 4 disturbers** dBm	**NEXT Power 10 disturbers** dBm	**NEXT Power 24 disturbers** dBm
0 – 1.544 MHz	14.1	– 50.2	– 47.8	– 45.5
0 – 3 MHz	14.6	– 48.3	– 45.9	– 43.6
0 – 10 MHz	14.6	– 48.0	– 45.6	– 43.3

For testing, the T1 NEXT powers in table B.3 and PSD curves in figure B.3 have been adjusted downward by a total of 15.5 dB to take account of (a) the reduced coupling from an adjacent binder group (10 dB) and (b) an average separation between disturbing T1 transmitter and ADSL receiver (5.5 dB)

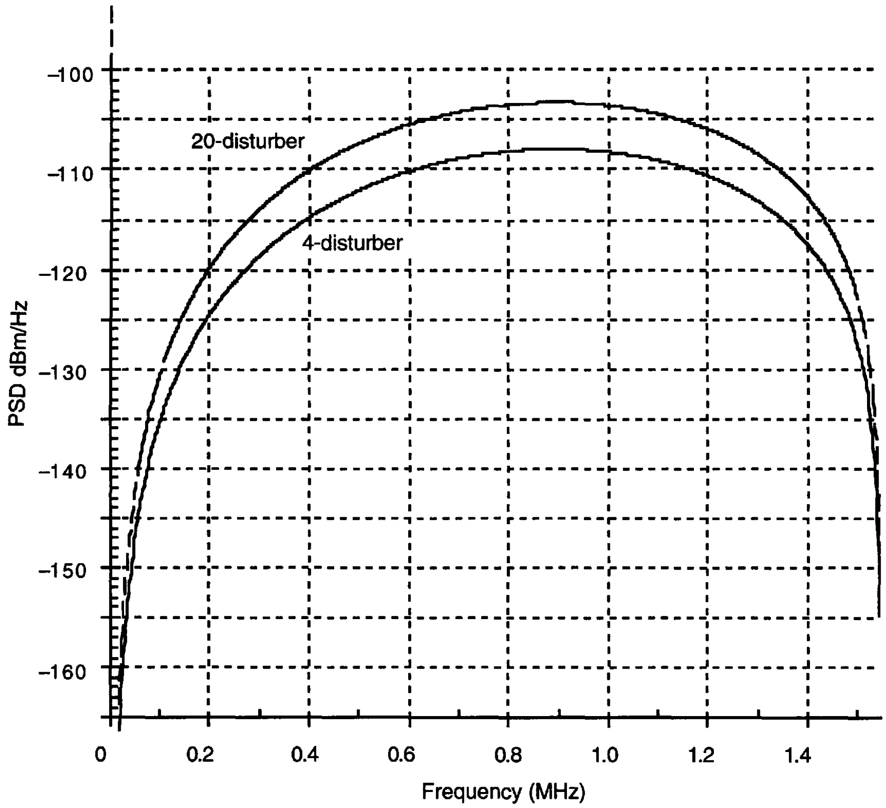


Figure B.3 – 4 and 20-disturber T1 NEXT

B.4 Simulated ADSL power spectral density and induced FEXT

The PSD of ADSL disturbers is expressed as:

$$PSD_{\text{ADSL-Disturber}} = K_{\text{ADSL}} \times \frac{2}{f_o} \times \frac{\left[\sin\left(\frac{\pi f}{f_o}\right)\right]^2}{\left(\frac{\pi f}{f_o}\right)^2} \times |LPF(f)|^2 \times |HPF(f)|^2 , \qquad 0 \le f < \infty$$

where $f_o = 2.208 \times 10^6$Hz, $K_{\text{ADSL}} = 0.1104$Watts,

This equation gives the single sided PSD, where K_{ADSL} is the total transmitted power in Watts for the downstream ADSL transmitter before shaping filters, and is set such that the ADSL PSD will not exceed the maximum allowed PSD. f_o is the sampling frequency in Hz and

$$|LPF(f)|^2 = \frac{1}{1+\left(\frac{f}{f_{3dB}}\right)^8} , \qquad f_{3dB} = 1.104 \times 10^6\text{Hz}$$

is a fourth order low pass filter with a 3 dB point at 1104 kHz, and

$$|HPF(f)|^2 = \frac{f^8}{f^8 + f_{3dB}{}^8} , \qquad f_{3dB} = 20 \times 10^3\text{Hz}$$

is a fourth order high pass filter with a 3 dB point at 20 kHz, separating ADSL from POTS. With this set of parameters the PSD_{ADSL} is the PSD of a downstream transmitter that uses all the channels.

The FEXT loss model is:

$$|H_{\text{FEXT}}(f)|^2 = |H_{\text{channel}}(f)|^2 \times k \times l \times f^2$$

where H_{channel} (f) is the channel transfer function, k is the coupling constant and is $3.083\text{x}10^{-20}$ for 10, 1% worst-case disturbers, l is the coupling path length in feet and equals 9000 ft for CSA #6, and f is in Hz. The FEXT noise PSD is therefore:

$$PSD_{\text{ADSL-FEXT}} = PSD_{\text{ADSL}} \times |H_{\text{FEXT}}(f)|^2$$

The integration of PSD_{ADSL} and $PSD_{\text{ADSL-FEXT}}$ over the various frequency ranges is shown in table B.4.

Table B.4 – PSD_{ADSL} and $PSD_{\text{ADSL-FEXT}}$ power with shaping and coupling transformer

Frequency range	Transmit power dBm	FEXT Power 10 disturbers dBm	FEXT power 24 disturbers dBm
0 – 1.104 MHz	19.0	– 69.6	– 67.3
0 – 2.204 MHz	19.2	– 69.6	– 67.3
0 – 4.416 MHz	19.2	– 69.6	– 67.3

Figure B.4 shows the theoretical PSD of 10-disturber downstream ADSL FEXT on CSA loop #6.

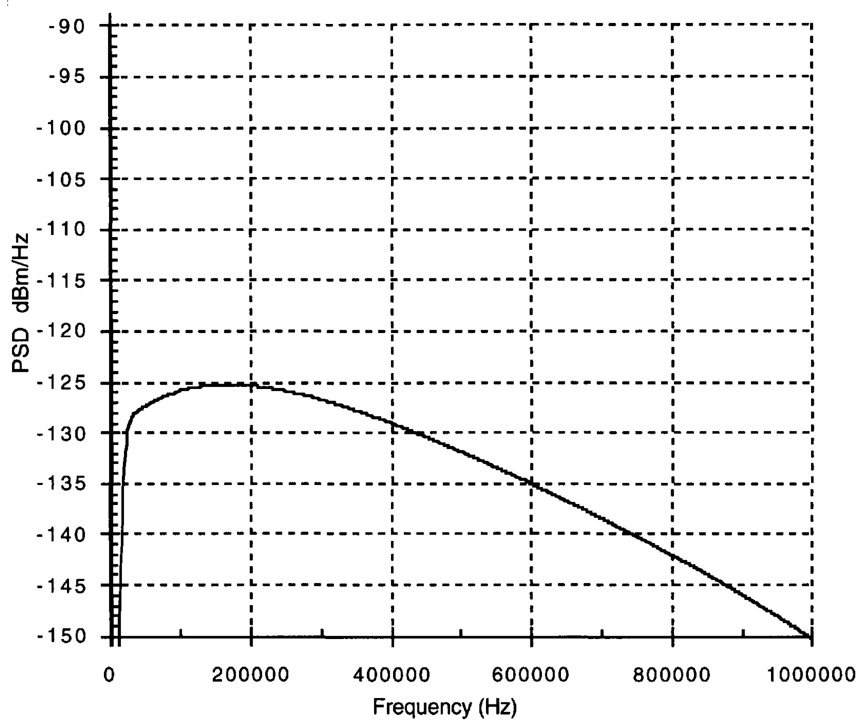


Figure B.4 – Theoretical 10-disturber ADSL FEXT

B.5 Simulated ADSL-induced NEXT into the downstream signal

The upstream ADSL signal nominally occupies the band from 25 to 138 kHz, but the upper sidelobes of the pass-band signal beyond 138 kHz may also contribute to the NEXT into the downstream signal. Their effect will depend on the method of anti-aliassing used in the remote transmitter, which issue is addressed in 7.12.3. The PSD of the upstream ADSL NEXT can be expressed as:

$$PSD_{\text{ADSL-NEXT}} = PSD_{\text{ADSL,us-Disturber}}\left(x_n f^{\frac{3}{2}}\right), \qquad 0 \le f < \infty$$

where x_{10} is defined in B.1. $PSD_{\text{ADSL,us-disturber}}$ is difficult to define precisely because of the various sidelobes of the passband signals. For simplicity, the transmit PSD mask given in 7.12 will be used; i.e., – 38 dBm/Hz from 28 kHz to 138 kHz, – 62 dBm/Hz at 181.125 kHz, and – 86 dBm/Hz at 224.25 kHz, with a straight-line fit on a logarithmic scale for the transmit PSDs between 138 kHz and 181.125 kHz, and between 181.125 kHz and 224.25 kHz. This transmit PSD is multiplied by the $(\text{sinc})^2$ term with f_o = 276 kHz to get the final $PSD_{ADSL,us\text{-}disturber}$. In particular, $PSD_{\text{ADSL,us-disturber}}$ can be expressed as:

$$PSD_{\text{ADSL,us-Disturber}} = K_{mask} \times \frac{\left[\sin\left(\frac{\pi f}{f_o}\right)\right]^2}{\left(\frac{\pi f}{f_o}\right)^2}, \qquad 0 \le f < \infty$$

where $f_o = 276 \times 10^3$Hz,

$$K_{mask} = -38 \text{ dBm/Hz} \qquad 28 \text{ kHz} \le f \le 138 \text{ kHz}$$

$$-38 - 24\left(\frac{f - 138000}{43125}\right) \text{dBm/Hz} \qquad f > 138 \text{ kHz}$$

Figure B.5 shows the theoretical PSD of 10-disturber ADSL NEXT.

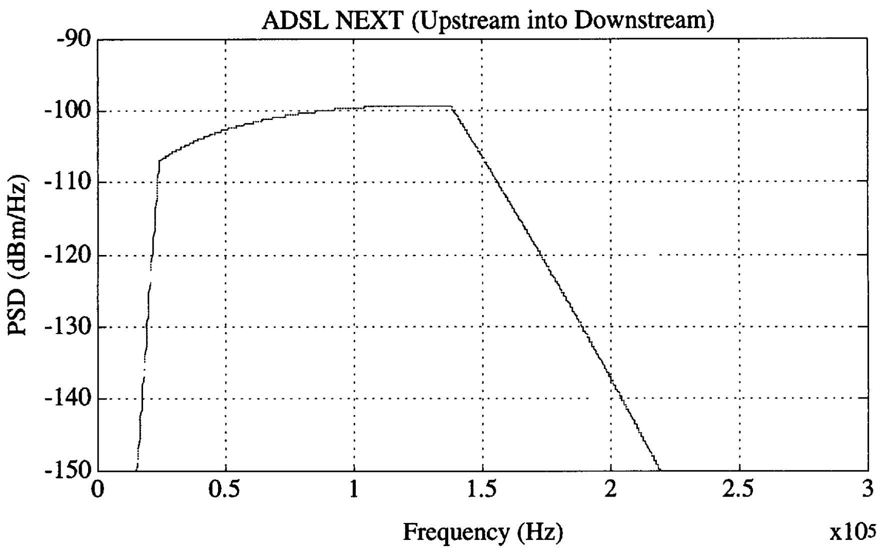


Figure B.5 – Theoretical 10-disturber ADSL NEXT

Annex C
(normative)

Characteristics of test impulse waveforms

The two test impulse waveforms specified in clause 15 of the standard are described in tables C.1 and C.2 with the impulse wave amplitude given in millivolts at 160 nanosecond time intervals. The specific means of generating these waveforms for test purposes is left to the implementor.

Table C.1 – Impulse number 1

Interval #	Amplitude mV	Interval #	Amplitude mV	Interval #	Amplitude mV
1	0.0000	51	– 6.3934	101	0.1598
2	0.0000	52	1.7582	102	– 1.7582
3	0.0000	53	2.2377	103	0.1598
4	0.0000	54	– 4.9549	104	0.4795
5	0.0000	55	2.2377	105	– 1.2787
6	0.0000	56	1.7582	106	0.7992
7	0.0000	57	– 5.5943	107	1.2787
8	0.0000	58	1.4385	108	– 0.7992
9	0.0000	59	2.3975	109	0.0000
10	0.9590	60	– 3.6762	110	– 0.3197
11	– 0.4795	61	1.4385	111	– 2.2377
12	– 1.2787	62	0.4795	112	– 1.1188
13	– 1.1188	63	– 5.7541	113	– 0.7992
14	– 1.4385	64	– 0.4795	114	– 1.5984
15	– 1.5984	65	0.3197	115	0.1598
16	– 2.2377	66	– 3.3566	116	0.4795
17	– 1.4385	67	2.3975	117	– 0.9590
18	7.6721	68	2.3975	118	0.0000
19	6.7131	69	– 3.1967	119	– 0.3197
20	– 16.6229	70	0.7992	120	– 1.5984
21	– 12.9467	71	0.6393	121	0.0000
22	18.7008	72	– 3.5164	122	0.4795
23	9.5902	73	1.1188	123	– 0.7992
24	– 13.5861	74	1.7582	124	0.4795
25	– 5.2746	75	– 2.3975	125	0.7992
26	– 6.3934	76	1.2787	126	– 0.9590
27	– 1.9180	77	0.9590	127	– 0.9590
28	23.0164	78	– 3.3566	128	– 0.4795
29	3.9959	79	0.0000	129	– 0.6393
30	– 23.4959	80	0.1598	130	0.4795
31	– 3.1967	81	– 3.0369	131	1.1188
32	4.3156	82	1.1188	132	0.0000
33	– 3.0369	83	1.5984	133	0.0000
34	10.7090	84	– 2.0779	134	0.0000
35	2.2377	85	0.1598	135	0.0000
36	– 12.9467	86	0.3197	136	0.0000
37	3.1967	87	– 2.5574	137	0.0000
38	1.9180	88	0.1598	138	0.0000
39	– 9.9098	89	0.1598	139	0.0000
40	5.5943	90	– 2.0779	140	0.0000
41	5.9139	91	0.6393		
42	– 6.7131	92	0.9590		
43	2.3975	93	– 1.7582		
44	1.2787	94	– 0.1598		
45	– 8.4713	95	– 0.6393		
46	2.5574	96	– 3.0369		
47	2.8771	97	– 0.3197		
48	– 6.0738	98	0.4795		
49	2.2377	99	– 1.4385		
50	1.7582	100	0.4795		

Table C.2 – Impulse number 2

Interval #	Amplitude mV	Interval #	Amplitude mV	Interval #	Amplitude mV
1	0.0000	51	0.6404	101	0.6404
2	0.0000	52	15.5295	102	0.6404
3	0.0000	53	18.8916	103	– 0.4803
4	0.0000	54	– 3.8424	104	– 0.3202
5	0.0000	55	– 3.0419	105	– 0.9606
6	0.0000	56	11.6872	106	– 2.8818
7	0.0000	57	– 0.3202	107	– 2.5616
8	0.0000	58	– 7.5246	108	– 0.8005
9	0.0000	59	13.4483	109	– 0.4803
10	– 0.6404	60	18.4113	110	– 0.8005
11	0.9606	61	– 0.4803	111	– 0.4803
12	0.1601	62	– 3.0419	112	– 0.9606
13	– 5.4433	63	9.7660	113	– 1.1207
14	– 12.3276	64	11.2069	114	– 0.6404
15	– 12.1675	65	4.0025	115	– 0.4803
16	0.0000	66	0.6404	116	– 0.9606
17	5.2832	67	0.6404	117	– 1.4409
18	0.1601	68	1.7611	118	– 1.6010
19	– 20.8128	69	3.3621	119	– 1.2808
20	– 45.3078	70	5.6034	120	– 0.9606
21	– 46.7487	71	7.8448	121	– 0.9606
22	– 28.9778	72	2.5616	122	– 1.2808
23	– 13.4483	73	– 4.6428	123	– 1.1207
24	0.6404	74	0.6404	124	– 1.1207
25	0.9606	75	10.7266	125	– 1.4409
26	– 14.4089	76	8.3251	126	– 1.4409
27	– 13.7685	77	1.9212	127	– 1.4409
28	– 9.4458	78	3.6823	128	– 2.0813
29	– 17.4507	79	4.3227	129	– 2.4015
30	– 2.5616	80	0.3202	130	– 1.9212
31	26.5763	81	2.7217	131	– 1.4409
32	16.1699	82	7.2044	132	– 1.1207
33	– 17.7709	83	3.2020	133	– 1.2808
34	– 17.1305	84	– 2.7217	134	– 1.9212
35	13.6084	85	– 1.4409	135	– 2.2414
36	27.0566	86	1.2808	136	– 2.2414
37	18.0911	87	1.4409	137	– 2.5616
38	14.2488	88	0.8005	138	– 3.0419
39	5.6034	89	0.1601	139	– 3.0419
40	– 8.1650	90	0.0000	140	– 2.5616
41	12.4877	91	1.1207	141	– 1.2808
42	37.3029	92	1.1207	142	– 0.1601
43	9.6059	93	0.6404	143	– 0.6404
44	– 18.8916	94	1.1207	144	– 2.5616
45	5.1231	95	0.6404	145	– 3.2020
46	22.2537	96	– 1.1207	146	– 3.0419
47	1.1207	97	– 0.8005	147	– 2.5616
48	– 0.9606	98	0.1601	148	– 2.0813
49	20.4926	99	– 1.2808	149	– 1.4409
50	14.2488	100	– 1.4409	150	– 1.6010

Table C.2 *(continued)*

Interval #	Amplitude mV	Interval #	Amplitude mV	Interval #	Amplitude mV
151	– 1.9212	201	– 0.8005	251	– 1.2808
152	– 1.9212	202	– 0.9606	252	– 1.6010
153	– 2.0813	203	– 1.6010	253	– 1.6010
154	– 2.4015	204	– 2.4015	254	– 1.4409
155	– 2.5616	205	– 2.5616	255	– 0.4803
156	– 2.5616	206	– 2.8818	256	0.4803
157	– 1.9212	207	– 2.7217	257	0.4803
158	– 1.6010	208	– 1.9212	258	– 0.4803
159	– 1.6010	209	– 1.1207	259	– 0.9606
160	– 1.9212	210	– 0.9606	260	– 1.1207
161	– 1.9212	211	– 1.1207	261	– 1.4409
162	– 2.0813	212	– 1.4409	262	– 1.2808
163	– 2.2414	213	– 1.7611	263	– 0.1601
164	– 2.5616	214	– 2.4015	264	0.3202
165	– 2.7217	215	– 2.5616	265	0.0000
166	– 2.2414	216	– 2.2414	266	– 0.4803
167	– 1.2808	217	– 1.7611	267	– 0.4803
168	– 1.2808	218	– 1.7611	268	– 0.4803
169	– 2.2414	219	– 1.4409	269	– 0.6404
170	– 3.0419	220	– 0.9606	270	– 0.4803
171	– 2.8818	221	– 0.8005	271	– 0.1601
172	– 2.5616	222	– 0.9606	272	0.0000
173	– 2.2414	223	– 1.6010	273	0.0000
174	– 1.9212	224	– 2.2414	274	– 0.1601
175	– 1.9212	225	– 2.4015	275	– 0.1601
176	– 2.2414	226	– 2.2414	276	– 0.4803
177	– 2.5616	227	– 1.9212	277	– 0.6404
178	– 2.7217	228	– 1.4409	278	– 0.3202
179	– 2.5616	229	– 0.4803	279	0.1601
180	– 2.4015	230	0.0000	280	0.4803
181	– 2.2414	231	– 0.6404	281	0.3202
182	– 2.0813	232	– 1.6010	282	– 0.1601
183	– 1.7611	233	– 1.7611	283	– 0.3202
184	– 1.6010	234	– 1.6010	284	– 0.4803
185	– 1.7611	235	– 1.9212	285	– 0.6404
186	– 2.2414	236	– 1.9212	286	– 0.4803
187	– 3.0419	237	– 1.4409	287	0.1601
188	– 3.2020	238	– 0.4803	288	0.6404
189	– 2.7217	239	0.0000	289	0.6404
190	– 1.9212	240	0.0000	290	0.4803
191	– 1.2808	241	– 0.6404	291	0.0000
192	– 0.9606	242	– 1.6010	292	– 0.6404
193	– 1.1207	243	– 2.4015	293	– 0.6404
194	– 2.0813	244	– 1.9212	294	– 0.4803
195	– 2.8818	245	– 0.9606	295	– 0.1601
196	– 3.0419	246	– 0.4803	296	0.4803
197	– 2.7217	247	– 0.1601	297	0.6404
198	– 2.7217	248	– 0.1601	298	0.4803
199	– 2.0813	249	0.0000	299	0.6404
200	– 1.4409	250	– 0.8005	300	0.4803

Table C.2 *(continued)*

Interval #	Amplitude mV	Interval #	Amplitude mV	Interval #	Amplitude mV
301	−0.1601	351	0.8005	401	0.9606
302	−0.9606	352	1.4409	402	0.6404
303	−0.9606	353	1.6010	403	0.4803
304	−0.1601	354	1.2808	404	0.6404
305	0.6404	355	0.6404	405	0.6404
306	0.8005	356	0.0000	406	0.4803
307	0.8005	357	−0.4803	407	0.3202
308	0.4803	358	−0.6404	408	0.1601
309	0.1601	359	0.0000	409	0.3202
310	−0.1601	360	0.8005	410	0.4803
311	−0.3202	361	1.4409	411	0.9606
312	−0.1601	362	1.6010	412	1.2808
313	0.0000	363	1.2808	413	0.9606
314	0.1601	364	0.6404	414	0.1601
315	0.6404	365	0.0000	415	−0.1601
316	0.8005	366	−0.4803	416	0.0000
317	0.6404	367	−0.1601	417	0.4803
318	0.4803	368	0.1601	418	0.8005
319	0.0000	369	0.9606	419	0.6404
320	−0.4803	370	1.4409	420	0.4803
321	−0.4803	371	1.6010	421	0.8005
322	0.1601	372	1.1207	422	0.8005
323	0.8005	373	0.3202	423	0.4803
324	0.8005	374	−0.4803	424	0.1601
325	0.6404	375	−0.4803	425	0.0000
326	0.1601	376	0.1601	426	0.0000
327	0.4803	377	0.8005	427	0.1601
328	0.4803	378	1.1207	428	0.3202
329	0.3202	379	1.1207	429	0.6404
330	−0.3202	380	0.9606	430	0.9606
331	−0.4803	381	0.6404	431	0.8005
332	0.0000	382	0.1601	432	0.3202
333	0.6404	383	0.0000	433	0.1601
334	1.1207	384	0.1601	434	0.0000
335	1.2808	385	0.6404	435	0.1601
336	0.6404	386	1.1207	436	0.1601
337	0.1601	387	0.9606	437	0.1601
338	−0.1601	388	0.6404	438	0.1601
339	0.0000	389	0.6404	439	0.6404
340	0.0000	390	0.6404	440	1.1207
341	0.1601	391	0.3202	441	0.9606
342	0.3202	392	0.0000	442	0.4803
343	0.8005	393	0.4803	443	0.0000
344	1.2808	394	1.1207	444	−0.3202
345	1.2808	395	1.1207	445	−0.3202
346	0.9606	396	0.6404	446	0.0000
347	0.1601	397	0.1601	447	0.1601
348	−0.8005	398	0.0000	448	0.6404
349	−0.9606	399	0.1601	449	0.9606
350	−0.1601	400	0.8005	450	0.8005

Table C.2 *(concluded)*

Interval #	Amplitude mV	Interval #	Amplitude mV	Interval #	Amplitude mV
451	0.6404	461	0.0000	471	0.0000
452	0.0000	462	– 0.9606	472	0.0000
453	– 0.8005	463	– 1.1207	473	0.0000
454	– 0.8005	464	– 0.4803	474	0.0000
455	0.0000	465	0.4803	475	0.0000
456	0.4803	466	1.1207	476	0.0000
457	0.6404	467	1.1207	477	0.0000
458	0.6404	468	0.6404	478	0.0000
459	0.8005	469	0.0000	479	0.0000
460	0.6404	470	0.0000	480	0.0000

Annex D
(normative)

Vendor identification numbers

Sixteen bits (hex coded from 0000 to FFFF) are reserved for vendor identification; these shall be used by the ATU-C in C-MSGS1 (see 12.6.4), and by the ATU-R in R-MSGS1 (see 12.7.6). The numbers (with 0000 and 0001 reserved) were randomly assigned to the thirty-seven initially identified companies as follows:

	Numerical (hexadecimal) order	Alphabetical order for the first 37	
0002	Westell, Inc.	Adtran	0012
0003	ECI Telecom	Alcatel Network System, Inc.	0022
0004	Texas Instruments	Amati Communications Corp.	0006
0005	Intel	Analog Devices	001C
0006	Amati Communcations Corp.	ADC Telecommunications	0014
0007	General Data Communications (GDC) Inc.	AT&T Network Systems	000A
0008	Level One Communications	AT&T – Paradyne	0011
0009	Crystal Semiconductor	AWA	0021
000A	AT&T – Network Systems	Aware, Inc.	000B
000B	Aware, Inc.	Brooktree	000C
000C	Brooktree	Crystal Semiconductor	0009
000D	NEC	DSC	0018
000E	Samsung	ECI Telecom	0003
000F	Northern Telecom, Inc.	Ericsson Systems	001E
0010	PairGain Technologies	Exar Corporation	001A
0011	AT&T – Paradyne	Fujitsu Network Trans. Systems	0026
0012	Adtran	GDC, Inc.	0007
0013	INC	IBM Corp.	0016
0014	ADC Telecommunications	INC	0013
0015	Motorola	Intel	0005
0016	IBM Corp.	Italtel	0024
0017	Newbridge Networks Corp.	Level One Communications	0008
0018	DSC	Motorola	0015
0019	Teltrend	National Semiconductor	0023
001A	Exar Corp.	NEC	000D
001B	Siemens Stromberg-Carlson	Newbridge Networks Corp.	0017
001C	Analog Devices	Nokia	001D
001D	Nokia	Northern Telecom, Inc.	000F
001E	Ericsson Systems	Orckit Communications, Inc.	0020
001F	Tellabs Operations, Inc.	PairGain Technologies	0010
0020	Orckit Communications, Inc.	Samsung	000E
0021	AWA	Siemens Stromberg-Carlson	001B
0022	Alcatel Network Systems, Inc.	SAT	0025
0023	National Semiconductor Corp.	Tellabs Operations, Inc.	001F
0024	Italtel	Teltrend	0019
0025	SAT – Société Anonyme de Télécommunications	Texas Instruments	0004
0026	Fujitsu Network Transmission Systems	Westell, Inc.	0002
0027	MITEL	MITEL	0027
0028	Conklin Instrument Corp.	Conklin Instrument Corp.	0028

Annex E
(informative)

Resistance and insertion loss characteristics of typical telephone cables

The tables E.1, E.2, and E.3 provide the calculated resistance and insertion loss between 100 ohm terminations of the loops shown in figure 38.

NOTE – The primary constants of both polyethylene insulated cable (PIC) and pulp insulated cable, at 0°F, 70°F, and 120°F, are specified in annex G of ANSI T1.601.

Table E.1 – Resistance and insertion loss values for test loops at 70°F

Loop #	Resist-ance ohms	Insertion loss dB Frequency kHz										
		20	40	100	200	260	300	400	500	600	780	1100
T1.601 # 7	1127	29.8	36.7	45.2	52.8	57.3	60.2	67.7	74.8	81.7	93.0	110
T1.601 # 9	877	27.6	36.4	52.5	47.5	55.7	62.0	60.3	71.5	72.2	82.7	96.2
T1.601 #13	909	26.6	34.1	47.9	48.3	55.7	61.3	62.2	71.4	74.1	85.3	100
CSA # 4	634	17.6	22.0	29.6	39.6	40.1	42.5	49.2	50.2	53.8	55.7	70.7
CSA # 6	751	20.0	24.4	30.1	35.2	38.2	40.2	45.1	49.9	54.4	62.0	73.6
CSA #7	562	17.3	20.9	26.8	39.3	37.8	38.6	43.1	49.9	57.9	60.2	72.7
CSA #8	630	19.2	22.8	27.7	34.4	38.3	40.8	46.9	52.4	57.4	65.4	77.8
Mid-CSA	501	13.3	16.2	20.0	23.4	25.4	26.8	30.1	33.2	36.3	41.3	49.1

Table E.2 – Resistance and insertion loss in dB for test loops 90°F

Loop #	Resist-ance ohms	Insertion loss dB Frequency kHz										
		20	40	100	200	260	300	400	500	600	780	1100
T1.601 # 7	1176	30.6	37.9	46.9	54.6	59.1	62.1	69.6	76.6	83.4	95.0	113
T1.601 # 9	915	28.4	37.5	53.4	49.1	57.2	63.1	61.9	72.8	73.6	84.2	98.1
T1.601 # 13	948	27.4	35.2	49.0	49.9	57.2	62.5	63.7	72.8	75.6	87.0	102
CSA # 4	658	18.0	22.6	30.4	40.3	41.0	43.5	50.0	50.9	54.3	56.6	71.6
CSA # 6	784	20.5	25.2	31.2	36.4	39.4	41.4	46.4	51.1	55.6	63.3	75.2
CSA # 7	586	17.9	21.6	27.7	40.0	38.7	39.5	44.1	50.9	58.8	61.4	74.0
CSA # 8	657	19.8	23.6	28.7	35.4	39.3	41.8	47.9	53.5	58.6	66.8	79.4
Mid-CSA	523	13.8	16.7	20.7	24.2	26.2	27.6	30.9	34.0	37.1	42.2	50.1

Table E.3 – Resistance and insertion loss in dB for test loops 120° F

Loop #	Resist –ance ohms	Insertion loss dB Frequency kHz										
		20	40	100	200	260	300	400	500	600	780	1100
T1.601 # 7	1250	31.9	39.6	49.4	57.4	61.8	64.8	72.3	79.3	86.1	97.9	116
T1.601 # 9	972	29.5	39.1	54.7	51.5	59.5	65.5	64.1	74.7	75.7	86.4	101
T1.601 # 13	1008	28.5	36.8	50.7	52.3	59.5	64.5	66.0	74.9	77.9	89.4	105
CSA # 4	704	18.9	23.8	32.2	41.9	42.8	45.2	51.5	52.8	56.0	58.7	74.1
CSA # 6	833	21.4	26.3	32.8	38.2	41.2	43.2	48.2	52.9	57.4	65.3	77.5
CSA # 7	623	18.7	22.6	29.1	41.2	40.0	40.9	45.5	52.5	60.2	63.2	76.0
CSA # 8	699	20.7	24.8	30.2	36.7	40.8	43.3	49.4	55.1	60.4	68.8	81.7
Mid-CSA	555	14.4	17.5	21.8	25.5	27.5	28.8	32.1	35.2	38.3	43.5	51.6

Annex F
(informative)

Overvoltage, surge protection, and EMC

This standard describes the electrical characteristics of the ADSL access signals appearing at the NI, and the physical interface between the network and the CI . Phenomena such as lightning and overvoltages due to inductive interference or power crosses lie beyond the scope of this standard. However, these and other topics are discussed in the following readily available documents.

– ANSI/IEEE C62.42-1986, *Guide for the application of gas tube arrester low-voltage surge-protective devices;*

– Technical reference TR-EOP-000001, *Lightning, radio frequency and 60-Hz disturbances at the Bell operating company network interface*, Issue 2, Bellcore, Piscataway, N.J., June 1987.

Both the above documents contain useful information on the application of surge arresters and the loop electrical environment.

– ANSI/EIA/TIA 571-1991, *Environmental considerations for telephone terminals*.
This standard discusses the normal operating environment of the telephone terminal equipment, fire hazards, and protection.

– ANSI/UL 1459-1992, *Standard for telephone equipment.* This standard deals with safety considerations for telephone equipment.

– Bodle, D.W. ; Gresh, P.A. *Lightning surges in paired telephone cable facilities.* Bell Syst. Tech. J. 40: 1961 March.

– Gresh, P.A. *Physical and transmission characteristics of customer loop plant*. Bell Syst. Tech. J. 48: 1969 December.

– Heirman, Donald N. *Time variations and harmonic content of inductive interference in urban/suburban and residential/rural telephone plants*. IEEE, 1976 Annals No. 512C0010.

– Carrol, R. L.; Miller, P. S. *Loop transients at the customer station.* Bell Syst. Tech. J. 59(9): 1980 November.

– Carrol, R. L. *Loop transients measurements in Cleveland*, South Carolina. Bell Syst. Tech. J. 59(9): 1980 November.

– *Measurement of transients at the subscriber termination of a telephone loop*, CCITT, COM V-No. 53 (November 1983)

– Batorsky, D. V.; Burke M.E., 1980 *Bell system noise survey of the loop plant*. AT&T Bell Lab. Tech. J. 63(5): 1984 May-June.

– Koga, Hiraki; Motomitsu, Tamio *Lightning-induced surges in paired telephone subscriber cable in Japan*. IEEE Trans. Electromag. Comp. EMC-27: 1985 August.

– Clarke, Gord; Coleman, Mike. *Study sheds light on overvoltage protection.* Telephony. 1986 November 24.

The power emitted by the ADSL is limited by the requirements in this standard. Notwithstanding any information contained or implied in this standard, it is assumed that the ADSL will comply with applicable FCC requirements on emission of electromagnetic energy. These requirements may be found in the Title 47, Code of Federal Regulations, Part 15 and Part 68, and other FCC documents.

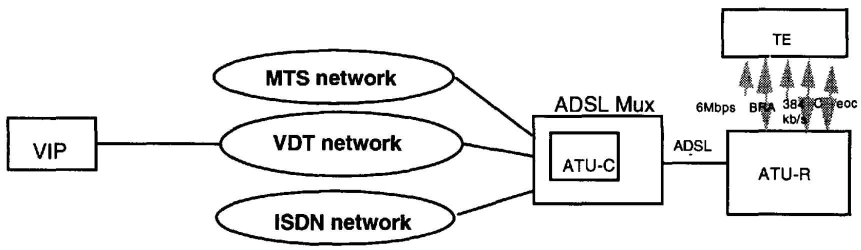
Annex G
(informative)

Examples of ADSL services and applications

G.1 Services and applications

Figure G.1 presents a basic network architecture for ADSL.

The market for ADSL services and applications can be segmented in various ways. Some potential application groups include: *entertainment, educational/institutional, telecommuting, small businesses* and *gaming.*



VDT – Video-dialtone
VIP – Video information Provider

Figure G.1 – Basic network architecture for ADSL

ADSL based services can offer users one major new innovation: real-time interactive multimedia services. In addition, the ability to support other application groups is important given that many homes are limited to a single copper pair.

The digital video revolution is opening opportunities for new classes of residential applications. Some of the potential applications can be grouped into the following categories, with examples of each group:

- Entertainment:
  - *movies on demand:* end-user dials into a service provider's network to access a listed movie;
  - *music on demand:* end-user dials into a service provider's network to access listed music;
  - *interactive TV:* end-user can access live and/or stored video/graphics, search with the help of pull-down menus, select a channel or channels of choice, and view more than one channel.

- Educational/Institutional:
  - *distant classrooms:* end-user can participate in a class remotely and interactively;
  - *on-line books and manuals:* end-user can access books and manuals on-line with the capability to turn pages, go to a certain page, search with key words or subjects, highlight the lines on-line, or make scratch-notes on the side of the book or on a scratchpad;
  - *medical and health consultation:* end-user (hospital, say) can consult with, and transmit medical images to, a doctor at a remote site.

– Telecommuting:
  – *work-at-home:* end-user (an employee, say) can access employer's workstations, printers, facsimile machines on LANs/WANs etc.;
  – *video-conferencing:* end-user can participate in a video-conference remotely with video in downstream and audio in upstream along with the workstation and screen-sharing access.

– Small businesses:
  – *video-conferencing:* similar characteristics as Telecommuting;
  – *credit-card picture/signature verifications:* small businesses can access a bank's or credit-card company's authorization database, which transmits the card-holder's picture and signature to avoid fraud.

– Games:
  – *interactive games (user-to-server):* end-user is able to play a game interactively from a remote server with various controls;
  – *interactive games (user-to-user):* one end-user is able to play a game interactively with another distant end-user with various controls;
  – *off-track betting:* an individual can bet remotely on a live event from home.

G.2 ADSL applications characteristics

For the ADSL services listed in G.1, it is assumed that POTS will always be available with a control channel (C) and asymmetric channel (approximately 1.5, 3 or 6 Mbit/s). User will be able to subscribe to 2B + D and 384 kbit/s services. Some of the characteristics for the above listed services and applications are listed below for information only:

– Entertainment:
  – *movies on demand:*
    – high-quality video (≥ 1.5 Mbit/s) plus audio (≥ 64 kbit/s) downstream;
    – remote control with pause, forward, reverse capability (approx. 100 bits/s) upstream;
  – *music on demand:*
    – high-quality audio (384 kbit/s compressed or 1.5 Mbit/s with 16 bits PCM) downstream;
    – remote control with pause, forward, reverse capability (approx. 100 bits/s) upstream;
  – *interactive TV:*
    – high-quality video (≥ 1.5 Mbit/s) plus normal audio (≥ 64 kbit/s) downstream;
    – mouse or jockey control (≥ 16 kbit/s) upstream;

– Educational/Institutional:
  – *distant classrooms:*
    – high-quality video (> 3 Mbit/s) plus audio (384 kbit/s) downstream;
    – audio (384 kbit/s) upstream;
  – *on-line books and manuals:*
    – high-quality video (> 3 Mbit/s) plus data downstream;
    – mouse control for pull-down menus (max. of 64 kbit/s) upstream;
  – *medical and health consultation:*
    – high-quality video (> 1.5 Mbit/s) plus voice plus data downstream;
    – mouse-like controls to zoom-in and out on the graphical image being transmitted (≥ 64 kbit/s) upstream;

- Telecommuting:
  - *work-at-home:*
    - high-quality video (> 1.5 Mbit/s) plus voice plus data downstream;
    - audio (384 kbit/s) plus data upstream;
  - *video-conferencing:*
    - medium-quality video (≥ 1.5 Mbit/s) plus graphics plus data plus voice downstream;
    - graphics plus data plus voice (384 kbit/s total) upstream;

- Small businesses:
  - *screen-sharing:*
    - high-quality graphics (384 kbit/s) plus data plus voice downstream;
    - voice plus graphics (384 kbit/s) plus data upstream;
  - *video-conferencing:*
    - medium-quality video (1.5 Mbit/s) plus graphics plus data plus voice downstream;
    - video (1.5 Mbit/s) plus graphics plus data plus voice upstream;
  - *credit-card picture/signature verifications:*
    - high-quality graphics plus data plus voice (384 kbit/s for all together) downstream;
    - voice plus graphics plus data (384 kbit/s total) upstream;

- Games:
  - *interactive games (user-to-server and user-to-user):*
    - high-speed video (≥ 3 to 6 Mbit/s) plus audio downstream;
    - speech-recognition, audio, jockey or mouse controls (≤ 64 kbit/s) upstream;
  - *off-track betting:*
    - high-quality video (≥ 3 to 6 Mbit/s) plus audio plus data downstream;
    - audio plus data plus control (≤16 kbit/s) upstream.

Figure G.2 shows a mapping of downstream and upstream channel capacities with the services that can be supported.

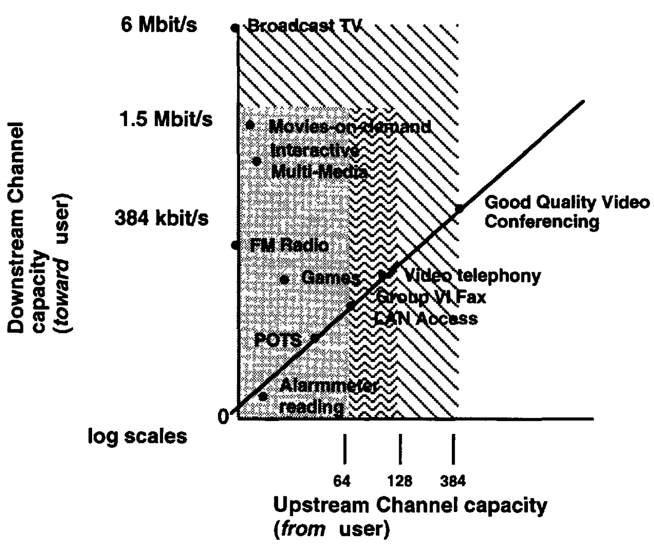


Figure G.2 – Applications based on upstream and downstream channel capacity

Annex H
(informative)[3]

Aspects of ADSL systems based on data rates at multiples of 2.048 Mbit/s

H.1 Scope

This annex provides clarification on options within the main body of the standard that relate to systems operating in a 2.048 Mbit/s environment (hereafter referred to as 2.048 Mbit/s applications). Note that only transport class 2M-3 is considered here.

H.2 Bearer channel allocations

The transport class and configuration of those allocations that are appropriate for 2.048 Mbit/s applications are shown in table H.1. The noise models and test loops presented in this annex are for bearer channel allocations as shown in table H.1.

Table H.1 – Bearer channel allocations for 2.048 Mbit/s applications

Transport class 2M-3 configuration	Simplex downstream rate (kbit/s)	Duplex rate(s) (kbit/s)
1	2048	160 (Note) 16 (C) (inc. analog POTS)
2	2048	16 (C) (inc. analog POTS)

NOTE – This rate is designed to accommodate ISDN-BRA (2B + D + overhead). Some carriers use a concatenated concept of V ref. points (e.g. concatenation of $V_1 + V_5$). Therefore, it might be desirable to limit the latency to a value of 1.25 ms per digital section and per ADSL system.

H.3 Noise models

Two noise sources are described for the testing of ADSL systems. These are frequency-domain sources that model the steady-state operating environment caused by crosstalk from adjacent wire pairs due to differing transmission systems. The two models differ because of the need to cater to countries that may or may not have HDB3-based primary rate systems operating at 2048 kbit/s in their access networks. Model A is for the case where no such interferors exist, while model B includes the crosstalk coupling effects of these types of systems.

H.3.1 Injection method

Test noise is applied as described in 15.3.1.1.

H.3.2 Crosstalk noise sources

The power spectral density of the crosstalk noise sources used for performance testing is given in figure H.1 for model A, and in figure H.2 for model B. Model A includes discrete tones, which represent radio frequency interference that is commonly observed, especially on wire pairs routed above ground. Further details of the specification of these noise models are shown in tables H.2 to H.4.

The resulting wideband noise power over the frequency range 1 kHz to 1.5 MHz for model A is -49.4 ± 0.5 dBm and for model B is -43.0 ± 0.5 dBm.

The noise probability density function shall be approximately Gaussian with a crest factor ≥ 5.

[3] This is an informative annex. However, the minimum requirements for performing the tests described in this informative annex are indicated by the word "shall."

The accuracy of the power spectral density shall be within ±1 dB over the frequency range 1 kHz to 1.5 MHz, when measured with a resolution bandwidth of 1 kHz.

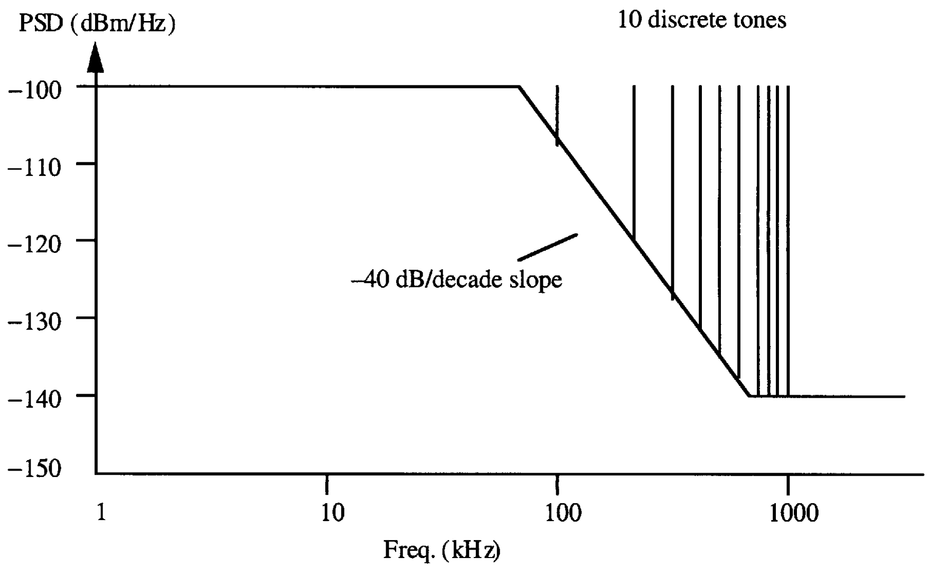


Figure H.1 – Single-sided noise power spectral density into 100 Ω for model A

Table H.2 – Coordinates for noise model A

Freq. kHz	**PSD** dBm/Hz	**PSD** µV/√Hz
1	– 100	3.16
79.5	– 100	3.16
795	– 140	0.03
1500	– 140	0.03

Table H.3 – Tone frequencies and powers for noise model A

Freq. kHz	Power dBm
99	– 70
207	– 70
333	– 70
387	– 70
531	– 70
603	– 70
711	– 70
801	– 70
909	– 70
981	– 70

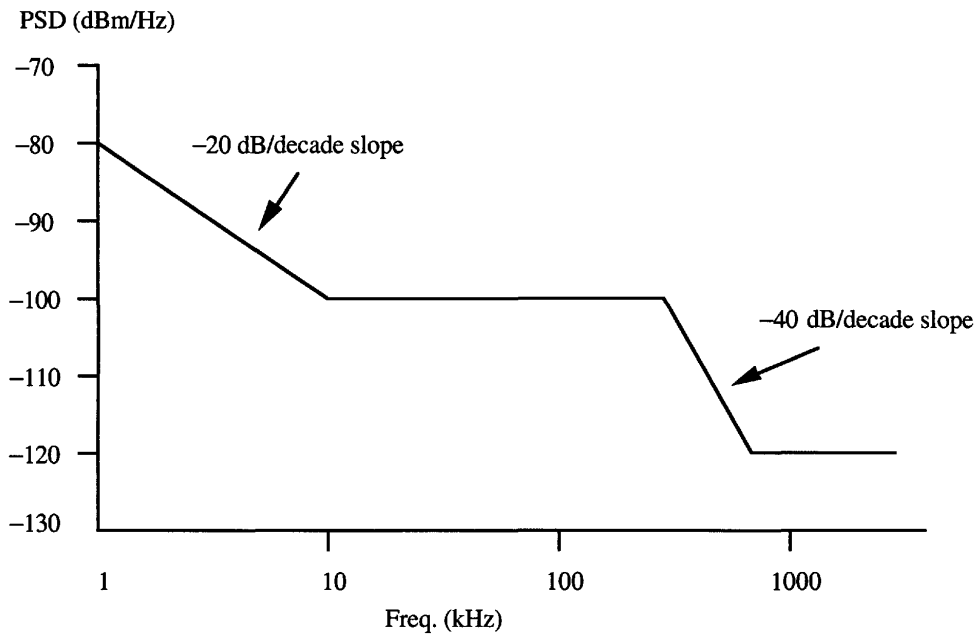


Figure H.2 – Single sided noise power spectral density into 100 Ω for model B

Table H.4 – Co-ordinates for noise model B

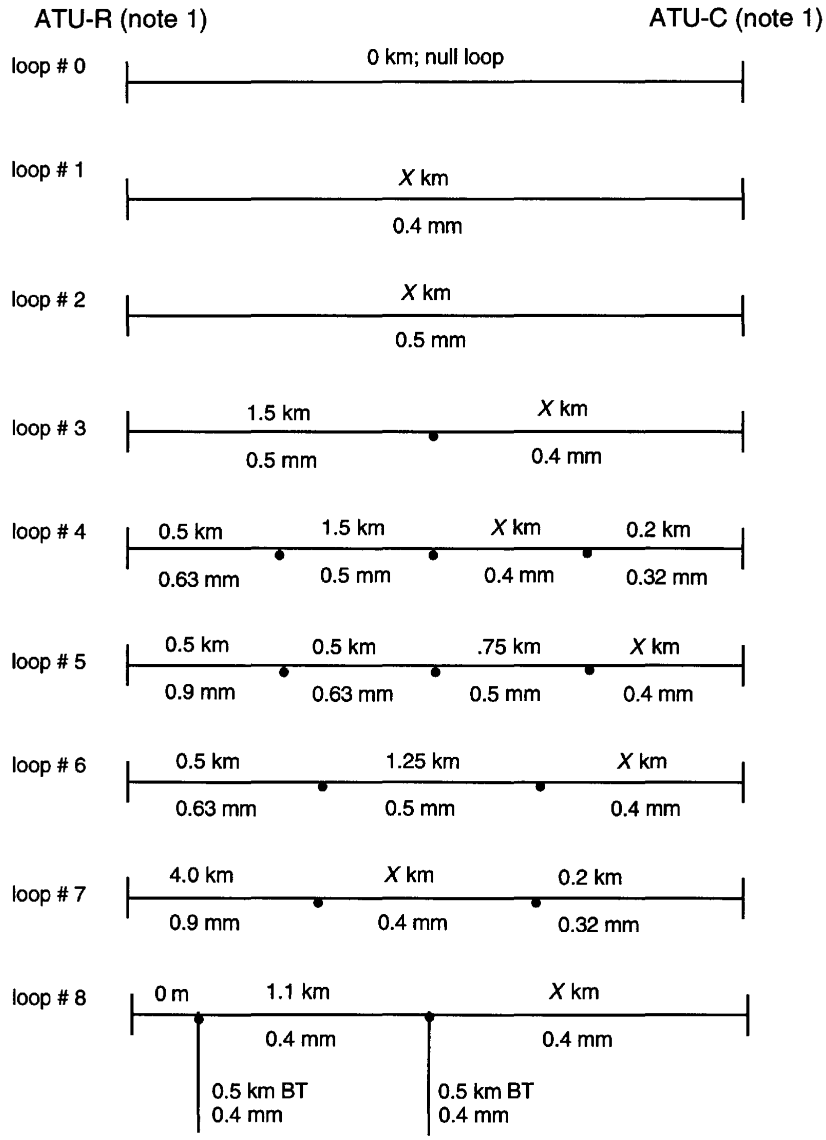
Freq. kHz	PSD dBm/Hz	PSD mV/√Hz
1	– 80	31.62
10	– 100	3.16
300	– 100	3.16
711	– 115	0.56
1500	– 115	0.56

H.4 Test loops

To test the performance of the ADSL system incorporating the bearer channel capabilities outlined in clause H.2, the test loops specified in figure H.3 shall be used. The power spectral density of the ADSL downstream transmission shall be as described in 6.13 of the standard with the exception that the power boost option shall not be used for test purposes.

The variation of the primary line constants (R, L and C) with frequency for the different reference cable types are given in tables H.9 – H.13. Note that the capacitance, C, is constant with frequency, and the conductance, G, is assumed zero. The RLC values are quoted per km at a temperature of 20°C and are measured values that have been smoothed.

Note also that there are adjustable sections (marked 'X') in figure H.3. The nominal lengths of these sections, which are shown in tables H.5 – H.8, are calculated from the reference RLC values for each cable type shown in tables H.9 – H.13. For repeatability of measurement results, however, the lengths of these sections shall be adjusted for each individual test loop to give the overall insertion loss shown in tables H.5 – H.8. Insertion loss is measured at 300 kHz with 100 Ω (balanced resistive) source and termination impedances.



NOTES
1 These test loops are shown with the ATU-Rs on the left; this is in contrast to fig. 38, where the ATU-Rs are on the right.
2 All cable is Polyethylene insulated.
3 1 km = 3.28 kft.
4 BT = Bridged tap (i.e., section of unterminated cable).

Figure H.3 – Test loop set for transport class 2M-3 configuration 1 or 2 operation with noise model A or B

Table H.5 – Loop-set insertion loss and nominal lengths for 2M-3 configuration 1 (noise model A)

Loop #	Nominal value of adjustable length 'X' km	Loop insertion loss at 300 kHz dB
1	3.45	49.0
2	4.55	49.0
3	2.30	49.0
4	1.80	49.0
5	2.40	49.0
6	2.25	49.0
7	1.35	49.0
8	1.50	43.0

Table H.6 – Loop-set insertion loss and nominal length for 2M-3 configuration 2 (noise model A)

Loop #	Nominal value of adjustable length 'X' km	Loop insertion loss at 300 kHz dB
1	3.60	51.0
2	4.80	51.0
3	2.50	51.0
4	2.00	51.0
5	2.55	51.0
6	2.40	51.0
7	1.55	51.0
8	2.10	51.0

Table H.7 – Loop-set insertion loss and nominal lengths for 2M-3 configuration 1 (noise model B)

Loop #	Nominal value of adjustable length 'X' km	Loop insertion loss at 300 kHz dB
1	2.45	35.0
2	3.20	34.0
3	1.30	35.0
4	0.80	35.0
5	1.40	35.0
6	1.25	35.0
7	0.40	35.0
8	1.00	35.0

Table H.8 – Loop-set insertion loss and nominal lengths for 2M-3 configuration 2 (noise model B)

Loop #	Nominal value of adjustable length 'X' km	Loop insertion loss at 300 kHz dB
1	2.55	36.0
2	3.40	36.0
3	1.40	36.0
4	0.90	36.0
5	1.50	36.0
6	1.35	36.0
7	0.50	36.0
8	1.10	36.0

Table H.9 – RLC values for 0.32, 0.4, and 0.5 mm PE cables

	0.32 mm cable C = 40 nF/km		0.4 mm cable C = 50 nF/km		0.5 mm cable C = 50 nF/km	
Freq kHz	R Ω/km	L µH/km	R Ω/km	L µH/km	R Ω/km	L µH/km
0.	409.000	607.639	280.000	587.132	280.000	587.132
2.5	409.009	607.639	280.007	587.075	280.007	587.075
10.	409.140	607.639	280.110	586.738	280.110	586.738
20.	409.557	607.639	280.440	586.099	280.440	586.099
30.	410.251	607.639	280.988	585.322	280.988	585.322
40.	411.216	607.639	281.748	584.443	281.748	584.443
50.	412.447	607.639	282.718	583.483	282.718	583.483
100.	422.302	607.631	290.433	577.878	290.433	577.878
150.	437.337	607.570	302.070	571.525	302.070	571.525
200.	456.086	607.327	316.393	564.889	316.393	564.889
250.	477.229	606.639	332.348	558.233	332.348	558.233
300.	499.757	605.074	349.167	551.714	349.167	551.714
350.	522.967	602.046	366.345	545.431	366.345	545.431
400.	546.395	596.934	383.562	539.437	383.562	539.437
450.	569.748	589.337	400.626	533.759	400.626	533.759
500.	592.843	579.376	417.427	528.409	417.427	528.409
550.	615.576	567.822	433.904	523.385	433.904	523.385
600.	637.885	555.867	450.027	518.677	450.027	518.677
650.	659.743	544.657	465.785	514.272	465.785	514.272
700.	681.138	534.942	481.180	510.153	481.180	510.153
750.	702.072	526.991	496.218	506.304	496.218	506.304
800.	722.556	520.732	510.912	502.707	510.912	502.707
850.	742.601	515.919	525.274	499.343	525.274	499.343
900.	762.224	512.264	539.320	496.197	539.320	496.197
950.	781.442	509.503	553.064	493.252	553.064	493.252
1000.	800.272	507.415	566.521	490.494	566.521	490.494
1050.	818.731	505.831	579.705	487.908	579.705	487.908
1100.	836.837	504.623	592.628	485.481	592.628	485.481

NOTE – G = 0 at all frequencies.

Table H.10 – RLC values for 0.63 and 0.9 mm PE cables

	0.63 mm cable C = 45 nF/km		**0.9 mm cable** C = 40 nF/km	
Freq kHz	**R** Ω/km	**L** µH/km	**R** Ω/km	**L** µH/km
0.	113.000	699.258	55.000	750.796
2.5	113.028	697.943	55.088	745.504
10.	113.442	693.361	56.361	731.961
20.	114.737	687.008	59.941	716.775
30.	116.803	680.714	64.777	703.875
40.	119.523	674.593	70.127	692.707
50.	122.768	668.690	75.586	682.914
100.	143.115	642.718	100.769	647.496
150.	164.938	622.050	121.866	625.140
200.	185.689	605.496	140.075	609.652
250.	204.996	592.048	156.273	598.256
300.	222.961	580.960	170.987	589.504
350.	239.764	571.691	184.556	582.563
400.	255.575	563.845	197.208	576.919
450.	270.533	557.129	209.104	572.237
500.	284.753	551.323	220.365	568.287
550.	298.330	546.260	231.081	564.910
600.	311.339	541.809	241.326	561.988
650.	323.844	537.868	251.155	559.435
700.	335.897	534.358	260.615	557.183
750.	347.542	531.212	269.745	555.183
800.	358.819	528.378	278.577	553.394
850.	369.758	525.813	287.138	551.784
900.	380.388	523.480	295.452	550.327
950.	390.734	521.352	303.538	549.002
1000.	400.816	519.402	311.416	547.793
1050.	410.654	517.609	319.099	546.683
1100.	420.264	515.956	326.602	545.663

NOTE – G = 0 at all frequencies.

H.5 ADSL/POTS splitter impedances

The design impedance for the POTS port of the splitter is application specific, and therefore outside the scope of this informative annex. Of particular importance are return loss and resultant sidetone levels. It is expected that some 2.048 Mbit/s applications will require that the splitter matches to a complex telephony impedance. Significant differences may exist between particular applications; examples are:

- telephony impedances;
- telephony return loss;
- out of (POTS) band signalling systems (e.g., subscriber private metering 11 kHz to 50 kHz);
- low frequency telemetry.

H.6 Testing

Performance testing is outlined in the main body of the standard (see clause 15). Note that differences exist here with respect to the crosstalk noise sources (see H.3.2) and the test loops (see clause H.4), and the addition of a maximum stress linearity test (see H.6.1). Further details appropriate for testing are given in the main body of the standard.

H.6.1 Maximum stress linearity test

This test stresses the ADSL system to ensure that adequate linearity is achieved in implementations. A modified Loop #1 from the loop-set given in figure H.3 is used for this test. The modification is detailed in table H.14. An additive white Gaussian noise source with a power spectral density of – 140 ±1 dBm/Hz over the frequency range 1 kHz to 1.5 MHz is applied at the ATU-R in place of the crosstalk source. A resolution bandwidth of 1 kHz is used for calibration of the power spectral density.

Table H.11 – Insertion loss (and nominal length) for Loop #1

Transport class 2M-3 configuration	**Nominal value of adjustable length 'X' of Loop #1** km	**Loop insertion loss at 300 kHz** dB
1	4.35	62.0
2	4.70	67.0

Annex I
(informative)

Items for further study

The following is a partial list of items in the text of the standard that are indicated as being for further study

– the nature of the premises distribution (e.g., bus or star, type of media);

– the use of upstream simplex bearer(s) (downstream simplex bearers are already specified);

– switching on demand among the configurations allowed by a given transport class and on-line reassignment of bearer channels;

– the entire framed 2.048 Mbit/s (optional) structure is treated as a bearer data stream; the use of a lower payload rate is for further study;

– support of the 576 kbit/s optional duplex rate in the default mode of transport classes 2, 3, and 2M – 2;

– other uses of the eoc5 bit besides the presently defined ATU-R "dying gasp";

– the use of R-ACK3;

– the effects of the POTS splitter on voice-band performance;

– other payload data rates;

– location of the POTS splitters separate from the ATUs;

– on-line change of data rates and reconfigurations;

– sensitivity of pilot tones to single-frequency interference;

– further definition of impulse noise performance requirements;

– the impact of ADSL signal transfer delay on ISDN transport.

Annex J
(informative)

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A Method to Reduce the Probability of Clipping in DMT-Based Transceivers

Denis J. G. Mestdagh and Paul M. P. Spruyt

***Abstract*—A new method allowing a reduction in the probability of clipping in discrete multitone (DMT)-based transceivers is described. The method does not use any kind of precoding and can easily be implemented within conventional DMT-transceivers. The main advantage of the proposed method is an improvement of system performance in terms of overall signal-to-noise ratios (SNR's): with the simplest implementation option of the proposed method, up to about 8 dB improvement in the SNR as compared with previously reported brute force clipping methods can be achieved.**

I. Introduction

THE *discrete multitone* (DMT) modulation technique is emerging as a very powerful technique for applications ranging from asymmetric digital subscriber line (ADSL), digital audio broadcast (DAB) to interactive video on demand (IVOD) over CATV networks [1]–[3].

A DMT signal is the sum of N independently quadrature amplitude modulated (QAM) signals each being carried over a distinct carrier frequency. The frequency separation of the N carriers is equal to $1/T$ where T is the time duration of a DMT symbol. The real part of the complex envelope of the generated DMT signal can be expressed as

$$A(t) = \text{Re}\left\{ \sum_{m=-\infty}^{+\infty} \sum_{k=0}^{N-1} [r_m^k \cdot e^{j2\pi(k/T)t} \cdot u(t-mT)] \right\} \quad (1)$$

where r_m^k denotes the QAM-phasor of carrier k (at frequency k/T) of the m-th DMT symbol and $(u)t$ is a rectangular transmit pulse of duration T.

In a practical transceiver, the DMT symbol (1) is generated by means of an inverse fast Fourier transform (IFFT) on the complex phasors $\{r_m^k\}, k \in [0, N-1]$ [4].

Fig. 1 shows the instantaneous amplitude $A(t)$ of two DMT symbols generated with two distinct sets of QAM-phasors $\{r_m^k\}_1$ and $\{r_m^k\}_2$, and $N = 256$. For both symbols, 16-QAM carrier modulation is assumed. A noticeable feature of the symbol in Fig. 1(b) as compared with the one in Fig. 1(a) is that it exhibits large amplitude spikes which arise when several frequency components add in-phase. These spikes may have a serious impact on the design complexity and feasibility of the transceiver's analog front-end (i.e., high resolution of D/A-A/D convertors and line drivers with a linear behavior over a large dynamical range). In addition, regulations can limit the peak envelope power or the probability of clipping [5]. The effect of amplitude clipping in DMT transceivers has been analyzed in the literature [6], [7] and methods based on encoding the input data in order to reduce the peak-to-average power ratio of the DMT signal have been proposed [8], [9]. The coding methods, however, require an increase in data rate and hence a reduction of the energy per bit for the same transmit power, resulting in performance degradation in terms of information handling capacity of the communication system.

In this letter, an alternative method is proposed. Since N is usually large (say $N \geq 128$), $A(t)$ can be accurately modeled as a Gaussian random process (central-limit theorem) with a zero mean and a variance σ^2 equal to the total signal power. Its probability density function (pdf), denoted as $p(x)$, is given by [6]

$$p(x) \cong \frac{1}{\sigma\sqrt{2\pi}} \cdot e^{-(x^2/2\sigma^2)}. \quad (2)$$

Therefore, large amplitude spikes arise very rarely (thanks to statistical averaging) so that by applying a specific processing (no coding) only on DMT signals whose amplitudes exceed a given amplitude A_{Clip}, one can obtain a DMT symbol stream with almost no amplitudes exceeding A_{Clip}.

The paper is organized as follows. Section II presents the basics of the proposed method. In Section III, the resulting improvement of system performance in terms of signal-to-noise ratio (SNR) is derived. Conclusions are reported in Section IV.

II. The Proposed Method

The basic idea behind the proposed method can be described as follows. Assume that the maximum amplitude of the clipped DMT signal, A_{Clip}, is chosen so that the probability of amplitude clipping is lower than a specified value. In the DMT transmitter, the symbols generated by the IFFT are analyzed by a peak detector which provides an indication of the presence or absence of amplitude clipping. According to this indication, two distinct actions are taken:

Case a: If the amplitude of the DMT symbol never exceeds A_{Clip}, then the symbol is sent to the transmitter front-end without any change.

Case b: If the generated DMT symbol has at least one sample whose amplitude exceeds A_{Clip}, then it is not passed directly to the transmitter front-end. Instead, the phasor of each QAM-modulated carrier is changed by means of a fixed phasor-transformation and a new DMT symbol is generated by the IFFT. By careful selection of the phasor-transformation, the probability of clipping this new symbol (second pass) will be very low. (The resulting overall clipping probability will be calculated later on.)

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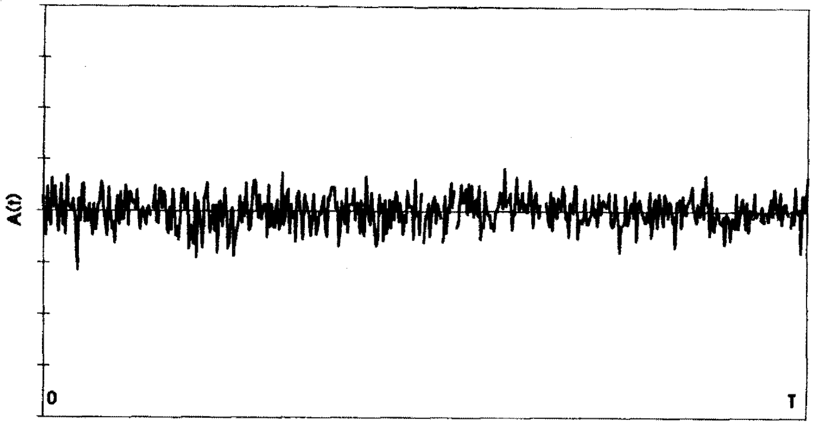
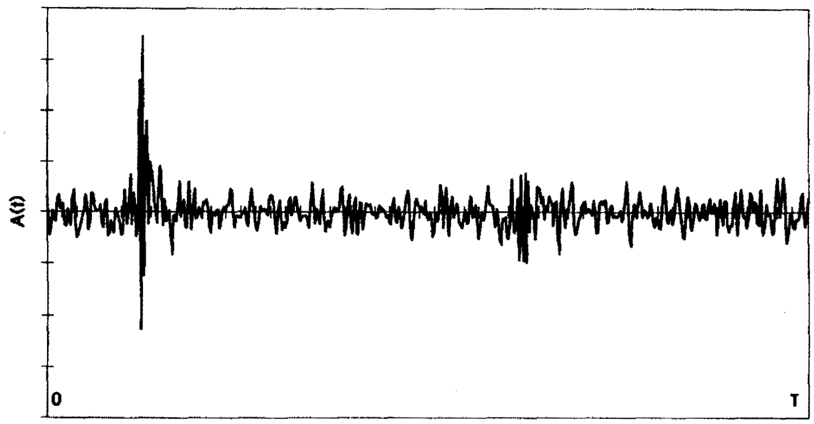


(a)



(b)

Fig. 1. Instantaneous amplitude $A(t)$ of two DMT symbols generated with two distinct sets of phasors $\{r_m^k\}_1$ and $\{r_m^k\}_2$, and $N = 256$.

The receiver at the far-end is informed about the application (or not) of the phasor-transformation at the transmitter, and applies the inverse transformation (Case b) or not (Case a) after demapping the QAM-modulated carriers. This extra information requires only one bit per DMT symbol. This bit could be provided by modulation of the pilot tone that otherwise carries no information and that is permanently used to maintain synchronization. Forward error correction coding and/or duplication of this information over another or several tones can be envisaged to improve the reliability of this data recovery.

Many phasor-transformations can be used. An easy-to-implement fixed random phasor transformation (known at the receiver) will be considered in what follows. Several other (more involved) transformations can be used as well without affecting the main results presented here.

The overall probability of clipping with the "two-pass" method described above can readily be obtained using (2). The probability that a given sample in the DMT symbol has an absolute amplitude larger than A_{Clip} ($A_{\text{Clip}} > 0$) is simply given by

$$P = 2 \cdot \int_{A_{\text{Clip}}}^{+\infty} p(x)\, dx = 1 - \text{erf}\left(\frac{A_{\text{Clip}}}{\sqrt{2} \cdot \sigma}\right) \tag{3}$$

where $\text{erf}(t)$ is the error function defined by

$$\text{erf}(t) = \frac{2}{\sqrt{\pi}} \cdot \int_0^t e^{-y^2}\, dy \cong 1 - \frac{e^{-t^2}}{t\sqrt{\pi}} \cdot \left[1 - \frac{1}{2t^2}\right].$$

Assuming $2N$ independent samples per DMT symbol, the probability that the symbol must be clipped after the first pass (i.e., at least one sample has an absolute amplitude larger than A_{Clip}) is given by

$$P_{\text{Clip}/1} = 1 - (1 - P)^{2N}. \tag{4}$$

The validity of (4) has been confirmed with great accuracy (better than 1%) by extensive computer simulations.

We assume that due to the random phasor-transform (with large N), the probability that the symbol must be clipped after the second-pass, $P_{\text{Clip}/2}$, is equal to $P_{\text{Clip}/1}$. This is particularly the case if the transformation is a random bijection

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line of any length, a POSITA would not have considered Shively's bit-spreading technique to be limited to being used on only long lines.

V. Likelihood of phase alignment of random data and data using Shively's bit spreading technique

15. DMT systems generally sought to randomize the data being transmitted to reduce the likelihood of phase alignment among the multiple carriers used to transmit data. To do so, they typically employed a bit-scrambler that would apply an exclusive-OR operation between each bit being transmitted and a bit generated by pseudorandom number generator. The resulting stream of bits encodes the desired data but is mathematically pseudorandom. The ANSI T1.413-1995 standard describes a typical arrangement in Section 6.3. See ANSI T1.413-1995, p. 35. A corresponding pseudorandom number generator in the receiver and another exclusive-OR operation could then be used to recover the original data bits.

16. When a bit-scrambled data stream is transmitted, the bits are mapped to QAM symbols that then specify the phase of each carrier. Since the bits are pseudorandom, the QAM symbols are pseudorandom, and the resulting carrier phases are pseudorandom.[1] This makes the amount of phase-alignment among the

[1] To be exact, the phase of each carrier is pseudorandomly selected from a discrete number of possible phase values, which depend on the modulation scheme. QAM-

carriers also be pseudorandom, so that the sum of the signals (representing the power required to transmit the summed signal) can be appropriately approximated using a Gaussian random variable. When the carriers' phase-alignment is not random (or pseudorandom), then the Gaussian approximation does not hold and should not be used. Shively's bit-spreading technique causes multiple carriers to be intentionally aligned, and therefore the likelihood of their alignment is no longer randomized. A system using Shively's bit-spreading technique cannot be reasonably approximated by a Gaussian random variable. Thus, Dr. Short was not correct in applying the Gaussian approximation to a system using Shively's bit-spreading technique. *See* Ex. 2003, ¶66.

17. The likelihood that a given number of carriers transmitting random symbols will all be phase-aligned depends on the number of carriers. Basically, with an increasing number of carriers, it becomes less likely that all of those carriers will be phase-aligned. The examples below further explain this concept.

18. First, consider the case in which single bits are transmitted by modulating the phases of individual carriers. This modulation scheme is known as

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4, for example, has four phase values. In systems with a sufficient number of carriers (such as the 256 carriers called for in ANSI T1.413-1995), the difference between (a) each carrier having one of a set number of possible phases and (b) each carrier having any phase value, is not significant.

binary phase shift keying ("BPSK"), because each carrier has one of two phase values. For example, the bit value of "0" can correspond to a sine wave, while the bit value of "1" can correspond to a sine wave with a 180º phase shift. If two bits are modulated onto two distinct carriers, the carriers will have the same phase when they encode the same bit values. As shown in Table I below, there are four possible combinations of bit values. In two of those combinations, the bit values are the same (either both "1" or both "0"). If all four possible combinations are equally likely (e.g., because the bit values are random), then the likelihood that both bits have the same value, and hence the likelihood of both carriers having the same phase, is 2 in 4, or 50%.

Table 1

Carrier #1	Carrier #2	Phases Aligned?
Bit = 0 Phase = 0º	Bit = 0 Phase = 0º	**Aligned**
Bit = 0 Phase = 0º	Bit = 1 Phase = 180º	Not aligned
Bit = 1 Phase = 180º	Bit = 0 Phase = 0º	Not aligned
Bit = 1 Phase = 180º	Bit = 1 Phase = 180º	**Aligned**

19. When three carriers are phase-modulated with three bits (one bit on each carrier), there are $2^3 = 8$ possible combinations of bit values on the carriers. The bits will all be the same only if they are all 0's or all 1's. Thus, the likelihood

of all three carriers carrying the same value, and therefore having the same phase, is 2 in 8, or 25%. This is illustrated using the Table 2 below:

Table 2

Carrier #1	Carrier #2	Carrier #3	Phases Aligned?
Bit = 0 Phase = 0º	Bit = 0 Phase = 0º	Bit = 0 Phase = 0º	**Aligned**
Bit = 0 Phase = 0º	Bit = 0 Phase = 0º	Bit = 1 Phase = 180º	Not aligned
Bit = 0 Phase = 0º	Bit = 1 Phase = 180º	Bit = 0 Phase = 0º	Not aligned
Bit = 0 Phase = 0º	Bit = 1 Phase = 180º	Bit = 1 Phase = 180º	Not aligned
Bit = 1 Phase = 180º	Bit = 0 Phase = 0º	Bit = 0 Phase = 0º	Not aligned
Bit = 1 Phase = 180º	Bit = 0 Phase = 0º	Bit = 1 Phase = 180º	Not aligned
Bit = 1 Phase = 180º	Bit = 1 Phase = 180º	Bit = 0 Phase = 0º	Not aligned
Bit = 1 Phase = 180º	Bit = 1 Phase = 180º	Bit = 1 Phase = 180º	**Aligned**

20. Similarly, when four carriers are phase-modulated with one bit per carrier, there are $2^4 = 16$ possible combinations of bit values. The likelihood of all four carriers carrying the same bit value, and thus having the same phase, is 2 in 16, or 12.5%. This is illustrated using the Table 3 below:

Table 3

Carrier #1	Carrier #2	Carrier #3	Carrier #4	Phases Aligned?
Bit = 0 Phase = 0º	Bit = 0 Phase = 0º	Bit = 0 Phase = 0º	Bit = 0 Phase = 0º	**Aligned**

Carrier #1	Carrier #2	Carrier #3	Carrier #4	Phases Aligned?
Bit = 0 Phase = 0º	Bit = 0 Phase = 0º	Bit = 0 Phase = 0º	Bit = 1 Phase = 180º	Not aligned
Bit = 0 Phase = 0º	Bit = 0 Phase = 0º	Bit = 1 Phase = 180º	Bit = 0 Phase = 0º	Not aligned
Bit = 0 Phase = 0º	Bit = 0 Phase = 0º	Bit = 1 Phase = 180º	Bit = 1 Phase = 180º	Not aligned
Bit = 0 Phase = 0º	Bit = 1 Phase = 180º	Bit = 0 Phase = 0º	Bit = 0 Phase = 0º	Not aligned
Bit = 0 Phase = 0º	Bit = 1 Phase = 180º	Bit = 0 Phase = 0º	Bit = 1 Phase = 180º	Not aligned
Bit = 0 Phase = 0º	Bit = 1 Phase = 180º	Bit = 1 Phase = 180º	Bit = 0 Phase = 0º	Not aligned
Bit = 0 Phase = 0º	Bit = 1 Phase = 180º	Bit = 1 Phase = 180º	Bit = 1 Phase = 180º	Not aligned
Bit = 1 Phase = 180º	Bit = 0 Phase = 0º	Bit = 0 Phase = 0º	Bit = 0 Phase = 0º	Not aligned
Bit = 1 Phase = 180º	Bit = 0 Phase = 0º	Bit = 0 Phase = 0º	Bit = 1 Phase = 180º	Not aligned
Bit = 1 Phase = 180º	Bit = 0 Phase = 0º	Bit = 1 Phase = 180º	Bit = 0 Phase = 0º	Not aligned
Bit = 1 Phase = 180º	Bit = 0 Phase = 0º	Bit = 1 Phase = 180º	Bit = 1 Phase = 180º	Not aligned
Bit = 1 Phase = 180º	Bit = 1 Phase = 180º	Bit = 0 Phase = 0º	Bit = 0 Phase = 0º	Not aligned
Bit = 1 Phase = 180º	Bit = 1 Phase = 180º	Bit = 0 Phase = 0º	Bit = 1 Phase = 180º	Not aligned
Bit = 1 Phase = 180º	Bit = 1 Phase = 180º	Bit = 1 Phase = 180º	Bit = 0 Phase = 0º	Not aligned
Bit = 1 Phase = 180º	Bit = 1 Phase = 180º	Bit = 1 Phase = 180º	Bit = 1 Phase = 180º	**Aligned**

21. Likewise, when eight carriers are phase modulated with one bit per carrier, there are $2^8 = 256$ possible combinations of bit values. The likelihood of all eight carriers having the same phase is 2 in 256, or 0.78%.

22. In general, when *n* bits are modulated on *n* carriers, there are 2^n possible combinations of bit values. There are only two possible ways for all of the bit values to be the same (either all 0's or all 1's), so the likelihood of *n* carriers all having the same phase is:

$$\frac{2}{2^n} \qquad \text{Eq. 1}$$

23. Shively's technique changes the likelihood of multiple carriers having the same phase significantly. When Shively's bit-spreading technique is applied to the carriers, the bits on these carriers are no longer independent of one another. Instead, Shively's bit spreading technique intentionally modulates multiple carriers with the same bit, which results in these carriers having the same phase.

24. Shively suggests using groups of 4 carriers. Ex. 1011, 13:49-52. This means that the 4 carriers in each group will carry the same data and be modulated using the same symbol. Shively contemplates that the 4 carriers will collectively transmit a single bit of data, and thus they will have a 1-bit symbol. The phase-modulation of a single bit of data is known as BPSK. If 4 carriers use Shively's technique, the likelihood that these 4 carriers will phase-align is 100%. It is a stark contrast to 12.5% chance of phase alignment when the 4 carriers carry random bits. If 8 carriers use Shively's technique (two groups of 4), then the likelihood of all 8

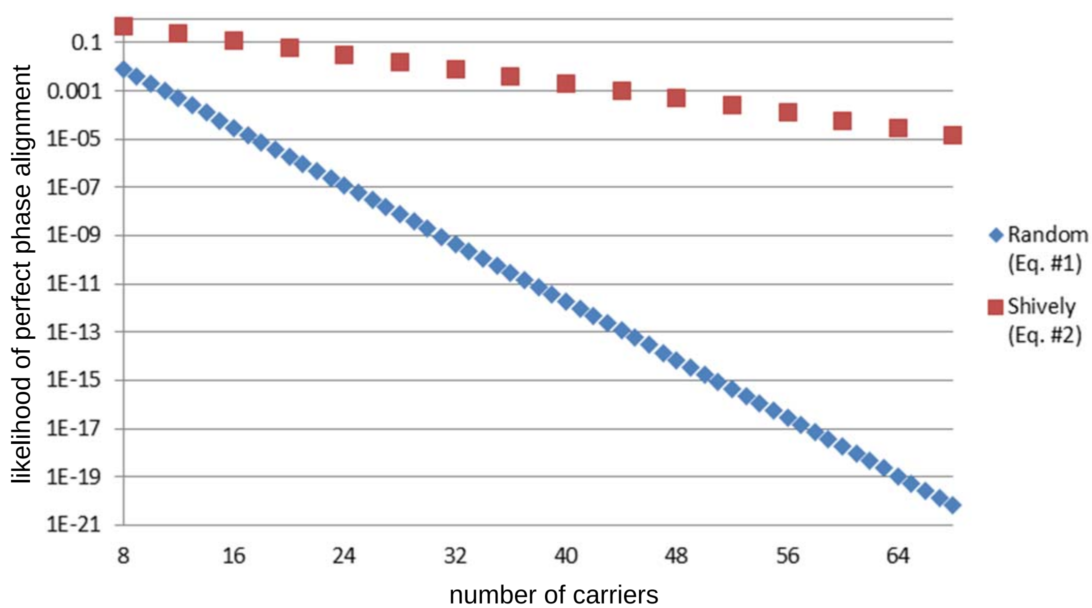
carriers being phase-aligned is 50%. Again, it is a stark contrast to the 0.78% chance if these same carriers carried random bits.

25. In general, when *n* bits are modulated onto *n* carriers that are divided into groups of 4, and each group carries the same bit values, there are $2^{n/4}$ possible combinations of bit values. So, the likelihood of *n* carriers all having the same phase if they are employing Shively's technique is:

$$\frac{2}{2^{\left(\frac{n}{4}\right)}} \qquad \text{Eq. 2}$$

26. Graphing equations #1 and #2 illustrates that probability of n-carriers having perfect phase alignment when carriers carry random bits and bits using Shively's bit spreading technique is never close, and only grows further apart as the number of carriers increase:

Graph 1



27. As illustrated above, the probability of carriers phase-aligning is radically different between the random-data case (equation #1) and the Shively's bit spreading technique case (equation #2).

28. The enormity of the differences also becomes apparent when considering how often the phases of carriers align in a multicarrier system, such as ADSL as defined by the ANSI T1.413-1995 standard. ADSL transmits 4000 DMT symbols per second. ANSI T1.413-1995, p. 24. Table 4 below summarizes the frequency with which *n* carriers will have a perfect phase alignment when a given number of carriers carry random BPSK data (equation #1) and when they carry BPSK data using Shively's bit spreading technique (equation #2). To determine the frequency with which a set of carriers have perfect phase alignment, the likelihoods of equation #1 and equation #2 are multiplied by the DMT symbol rate (4000 symbols/second).

Table 4

Number of phase-aligned carriers	**Random data frequency**	**Shively frequency**
4	500 times per second	4000 times per second
8	31 times per second	2000 times per second
16	Once every 8 seconds	500 times per second
24	Once every 35 minutes	125 times per second
32	Once every 6 days	31 times per second
48	Once every 1100 years	2 times per second
52	One every 17,850 years	Once per second

29. In his analysis of an 18,000 foot cable, Dr. Short determined that a maximum of 16 carriers (4 groups of 4) carried bits using Shively's bit spreading technique. Ex. 2003, ¶66. Dr. Short's analysis is flawed because, in assuming a Gaussian approximation, he treats Shively's carriers as if they carried random data and thus grossly underestimates the likelihood that those carriers will have their phases align. Dr. Short erroneously assumed that Shively's bit spreading technique will, on average, cause all 16 carriers to have the same phase about once every 8 seconds. But Table 4 demonstrates that Shively's bit spreading technique will cause all 16 carriers to align approximately *500 times* per second. Thus, Dr. Short's numerical analysis is based entirely on an erroneous assumption and is unreliable.

VI. The 12,000 foot cable example shows how Shively's technique increases PAR and the likelihood of signal clipping

30. Dr. Short stated that his analysis of an 18,000 foot narrow gauge and high loss (AWG26) cable without crosstalk is based in part on Figure 6 in Exhibit 2009. Ex. 1027, 32:2-8. Figure 6, replicated below, shows line attenuation for five different cable lengths.

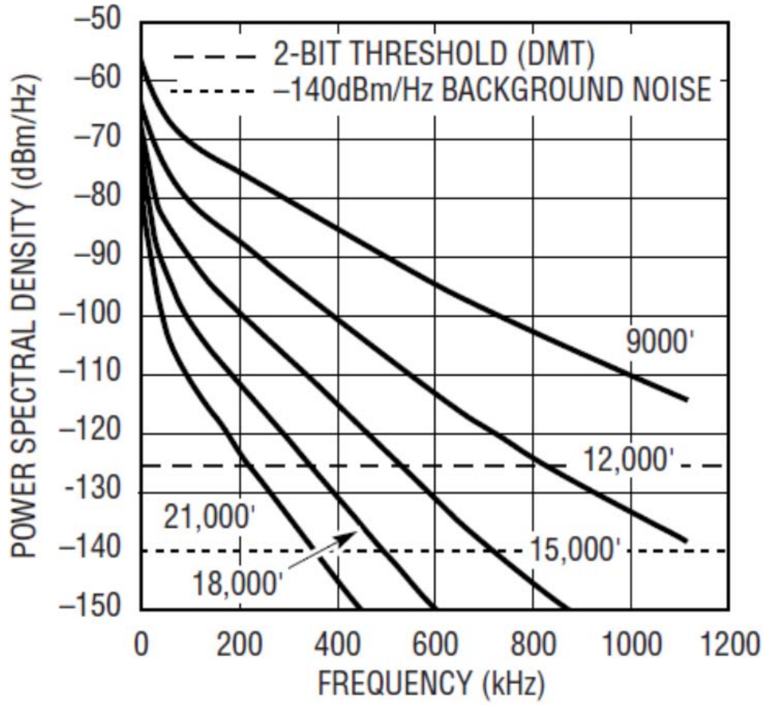


Figure 6. Typical received signal power spectral density, AWG26 loops

Ex. 2009, p. 31, Fig. 6.

31. Figure 6 shows line attenuation in the frequency band from 0 kHz to 1100 kHz, which generally corresponds to the frequency range used for communication in the ANSI T1.413-1995 standard. The ANSI standard employs 256 carriers, with each carrier spaced 4.3125 kHz apart. ANSI T1.413-1995, p. 46. Because low frequency carriers, such as carriers #1 through #6, are often reserved for analog voice and a guardband, ADSL services typically start with carrier #7. Ex. 1016, p. 187. Thus, out of 256 carriers there may be 250 downstream carriers

that can carry ADSL data.[2] It is appropriate to focus on the use of Shively's technique in the downstream direction because it generally uses more carriers than the upstream direction, so the engineering considerations regarding signal power and PAR are generally greater for the downstream direction.

32. In his analysis of an 18,000 foot cable, Dr. Short categorizes the carriers into three groups:

- Unimpaired carriers are those carriers above a threshold that can be used for ordinary ADSL communication (i.e., above the 2-BIT THRESHOLD (DMT) shown in Figure 6). Unimpaired carriers can

[2] The availability of 250 downstream carriers is for systems employing echo cancellation, allowing the upstream subchannels to also be used for downstream data. If echo cancellation is not used, then there will be fewer carriers used for downstream data. *See* ANSI T1.413-1995, p. 46:

> The channel analysis signal defined in 12.6.6 allows for a maximum of 255 carriers (at frequencies $n\Delta f$, n = 1 to 255) to be used. If echo cancelling (EC) is used to separate downstream and upstream signals, then the lower limit on n is determined by the ADSL/POTS splitting filters; if frequency division multiplexing (FDM) is used the lower limit is set by the down – up splitting filters. The cut-off frequencies of these filters are completely at the discretion of the manufacturer because, in either case, the range of usable n is determined during the channel estimation.

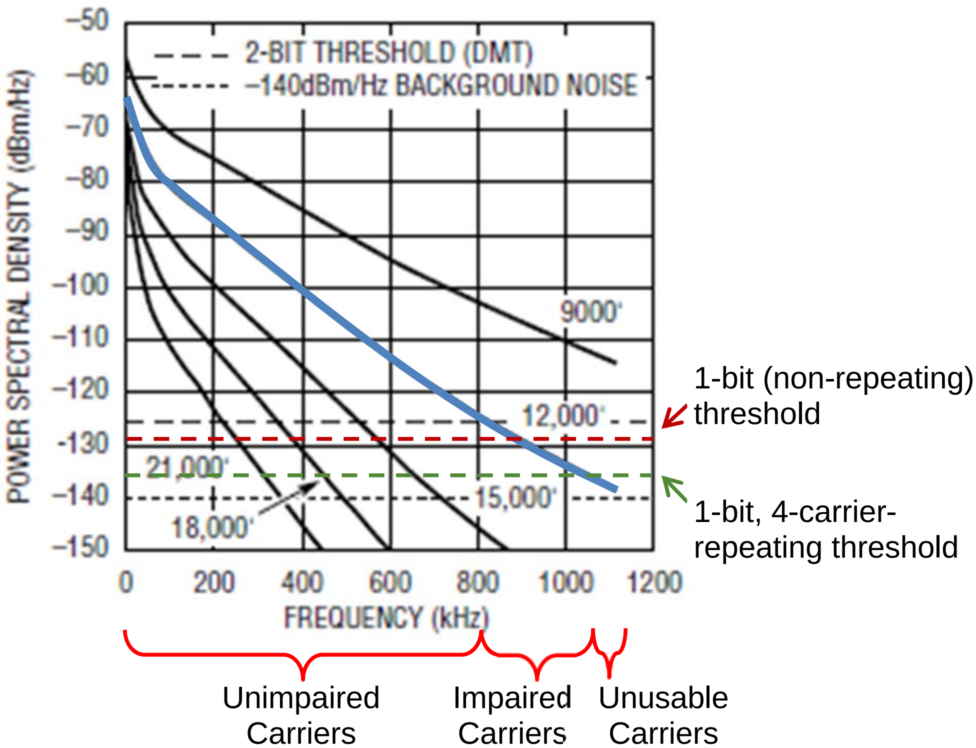
carry data with high probability of success. Ex. 2003, ¶¶ 27-28; Ex. 1027, 27:9-16.

- Impaired carriers are those carriers that cannot be used for ordinary ADSL communication (i.e., below the 2-BIT THRESHOLD) but are above the -140 dBm/Hz background noise floor. Impaired carriers can carry data using Shively's bit spreading technique. Ex. 2003, ¶¶ 49-50; Ex. 1027, p. 22:24-23:7 and 90:12-14.

- Unusable carriers are those carriers below the noise floor (-140 dBm/Hz). Unusable carriers are not used to carry data. Ex. 2003, ¶51; Ex. 1027, 28:17-20.

33. Below I have applied Dr. Short's categories to the 12,000-foot example shown in Dr. Short's source for attenuation information. To assist with applying Dr. Short's categories, I have annotated Fig. 6 with a horizontal line at -135 dBm/Hz, which approximates the minimum received signal strength required to reliably use a carrier to transmit one bit, when that carrier is part of a group of four carriers employing Shively's bit-spreading technique. I arrived at the -135 dBm/Hz value as follows: First, the 1-bit threshold would normally lie about 11.3 dBm/Hz above the -140 dBm/Hz noise floor, or at about -128.7 dBm/Hz. That value is approximately where Dr. Short drew his 1-bit threshold on Fig. 6. *See* Ex. 2003, ¶59. The annotated Figure 6 below shows the 1-bit threshold as a

dashed red line. Using Shively's bit-spreading technique across four carriers provides approximately 6 dB of coding gain, meaning that the 1-bit threshold when using Shively's technique is 6 dBm/Hz lower, at about -135 dBm/Hz.[3]



Ex. 2009, Fig. 6 (annotated).

[3] This analysis does not take into account a ± 3dB ripple permitted in the ANSI T1.413 power spectral density mask. *See* ANSI T1.413-1995, p. 48, Fig. 17. The power spectral density mask allows slightly more power (up to 3dB) to be put into carriers whose attenuated signal strength would be close to the -135 dBm/Hz threshold. By exploiting the ±3dB ripple, a transmitter could potentially extend the application of Shively's bit-spreading technique to even more carriers.

34. In effect, consideration of the minimum signal strength required to reliably transmit one bit when using Shively's technique (i.e., the -135 dBm/Hz threshold) differs from Dr. Short's description of the delineation between "impaired" and "unusable" carriers. Dr. Short's description would categorize carriers between -135 dBm/Hz and -140 dBm/Hz as "impaired," whereas I am categorizing them as "unusable" when Shively's technique is applied to groups of four carriers. However, using Shively's bit-spreading on these "unusable" carriers (for example, by spreading over more than 4 carriers to achieve greater coding gain) would only cause PAR to climb even higher.

35. When I apply Dr. Short's carrier categories to the 12,000 foot AWG26 attenuation graph, the carriers with frequencies from 0 to approximately 810 kHz are "unimpaired" carriers that can carry random data using ordinary ADSL modulation (e.g., QAM-4). The carriers with frequencies from approximately 810 kHz to approximately 1040 kHz are "impaired" carriers that could carry data using Shively's bit spreading technique. The carriers with frequencies approximately 1040 kHz to 1104 kHz are "unusable" carriers when Shively repeats one bit on four carriers.

36. To determine the number of unimpaired carriers, I divide the carriers in the unimpaired frequency range (0 kHz to 810 kHz) by the frequency width of

each carrier (4.3125 kHz). This analysis demonstrates that the 12,000 foot cable has approximately 188 unimpaired carriers (810 kHz / 4.3125 kHz = 188).

37. To determine the number of impaired carriers, I divide the carriers in the impaired frequency range (810 kHz to 1040 kHz, or 230 kHz) by the frequency width of each carrier (4.3125 kHz). This analysis demonstrates that the 12,000 foot cable has approximately 53 impaired carriers (230 kHz / 4.3125 kHz = 53.3). Using a similar approach, I calculate that the unusable frequencies between 1040 kHz and 1104 kHz correspond to approximately 15 unusable carriers: (1104 kHz – 1040 kHz) / 4.3125 = 14.8 carriers.

38. As I mentioned previously, the six lowest-frequency carriers were commonly left unused to avoid potential interference with ordinary analog voice communications. Thus, the 12,000 foot cable would *use* approximately 182 unimpaired carriers (188 – 6 = 182). Shively suggests an example that uses the bit-spreading technique with carriers arranged in groups of four, which would allow for 52 of 53 impaired carriers to carry repeated data (arranged in 13 groups of 4 carriers each). The leftover, 53rd carrier would be unused.

39. When 52 carriers (13 groups of 4) carry repeated data, varying numbers of carriers will align at different DMT symbols, thereby creating a spike in the transmission signal amplitude. For example, Table 4 illustrates that:

- any 8 carriers[4] (2 groups of 4) will perfectly align 2000 times per second;
- any 16 carriers (4 groups of 4) will perfectly align 500 times per second;
- any 24 carriers (6 groups of 4) will perfectly align 125 times per second;
- any 32 carriers (8 groups of 4) will perfectly align 31 times per second;
- any 40 carriers (10 groups of 4) will perfectly align 8 times per second;
- any 48 carriers (12 groups of 4) will perfectly align 2 times per second; and
- all 52 carriers (13 groups of 4) will perfectly align about once per second.

40. Because multiple carriers will align numerous times per second, these carriers will generate spikes in amplitude and lead to a significant increase in PAR.

[4] That is to say, for any selected two groups of four carriers, the likelihood of those two groups having the same phase is 50%, and thus at 4000 symbols per second, they will be exactly phase-aligned 2000 times per second.

41. Dr. Short stated that in the 18,000 foot cable example he considered, less than half of the carriers are usable. Because less than half of the carriers can transmit data, Dr. Short stated that the transmitter transmitting a signal over an 18,000 foot cable operates at less than half average power. This is not the case for a 12,000 foot cable. The 12,000 foot cable does has very few (15) unusable carriers. Thus, most of the available carriers could be transmitting data on a 12,000 foot cable. Thus, the transmitter transmitting data on all carriers could operate at close to full average power. Because Shively's technique increases the frequency with which a large number of carriers will be aligned and create a spike in signal amplitude, Shively's technique significantly increases PAR. For a transmitter that was designed to transmit a *random* signal multicarrier signal, attempting to transmit a signal using Shively's bit-spreading technique will cause a significant increase in signal clipping.

VII. A simulation of a transmitter shows that Shively's technique increases PAR and the likelihood of clipping

42. Because Shively's technique transmits the same bits on multiple carriers, a POSITA would have intuitively known that Shively's technique would significantly increase the likelihood of carriers' phases aligning, and therefore increase PAR.

43. A POSITA would also have known that quantifying the exact level of increase in PAR could not be calculated using a simple Gaussian approximation.

Instead, quantifying the increase in PAR would have called for running numerical simulations of a transmitter. Such simulations were commonly created and run by engineers in the 1990s to investigate the impact of proposed modulation techniques on a communication system's performance. A POSITA would have known how to create and run a simulation of Shively's bit-spreading technique. In order to quantify the increase in PAR, I designed and wrote a simulation of an ADSL transmitter that calculates the clipping probability of a DMT symbol for different values of PAR under different simulation conditions.

44. Exhibit 1034, provided with this declaration, is a true and accurate copy of the code for the simulation that I wrote, which runs in MathWorks Matlab or GNU Octave.

45. My simulation takes into account different scenarios that can occur when data is transmitted in an ADSL system. Equations #1 and #2 show the likelihood that all carriers will phase-align perfectly and generate a spike in power in a system that has *n* carriers. However, spikes can also occur when various carriers are only partially phase-aligned. Furthermore, the amplitude of a spike will depend in part on the specific frequencies of the carriers that are phase-aligned. Shively describes replicating data (a *k*-bit symbol) over adjacent carriers. Ex. 1011, 11:16-19.

46. In short, the PAR for any specific signal (and the likelihood that the signal will cause clipping) depends on the phase and amplitude of *all* of the carriers, not just those (for example) that are employing Shively's bit-spreading technique. My simulation takes all of these considerations into account by simulating the processing that a transmitter would perform on a random data stream, including:

- mapping the data for each subcarrier to a QAM symbol,
- grouping QAM symbols into a DMT symbol, and
- performing an inverse discrete Fourier transform on the DMT symbol to compute a time-domain signal.

The simulation then calculates the PAR of that time-domain signal. The simulation repeats this process for millions of transmission cycles (DMT symbols), aggregating the results to produce a graph showing the relationship between PAR and the likelihood that a time-domain signal with that PAR will cause clipping. This is a type of graph that a POSITA would have created in the 1990s to evaluate Shively's impact on PAR. Indeed, this is the type of graph that I presented in my PhD dissertation to show how the PAR reduction techniques I developed could achieve better-than-Gaussian performance. *See, e.g.*, Ex. 1025, p. 79, Fig. 4.2 & p. 93, Fig. 4.5.

47. Graph 2 shows the simulation results for four distinct scenarios, based in part on the attenuation of a 12,000 foot cable in TQ Delta's Exhibit 2009, p. 31, Fig. 6:

- Scenario #1: An all-carriers baseline simulates an ADSL transmitter employing QAM-4 modulation of random data on all 250 available downstream carriers. Because all 250 downstream carriers are modulated with random data the transmitter is operating on full average power. This simulates an ADSL transmitter where all carriers can be used, for example, the 9,000 foot cable and attenuation curve shown in Fig. 6 above.
- Scenario #2: A Gaussian distribution with the same power as the all-carriers baseline scenario. Note that the Gaussian curve is very close to the all-carriers baseline discussed above, which confirms that a Gaussian approximation can closely estimate the power required for a transmitter to transmit random data on all 250 downstream carriers with QAM-4 modulation.
- Scenario #3: A 12,000 foot baseline simulates an ADSL transmitter employing QAM-4 modulation of random data on 182 carriers. Because only 182 out of 250 downstream carriers are modulated with random data the transmitter is operating on approximately 73% of the full average power. This simulates the operating conditions of an ordinary ADSL transmitter

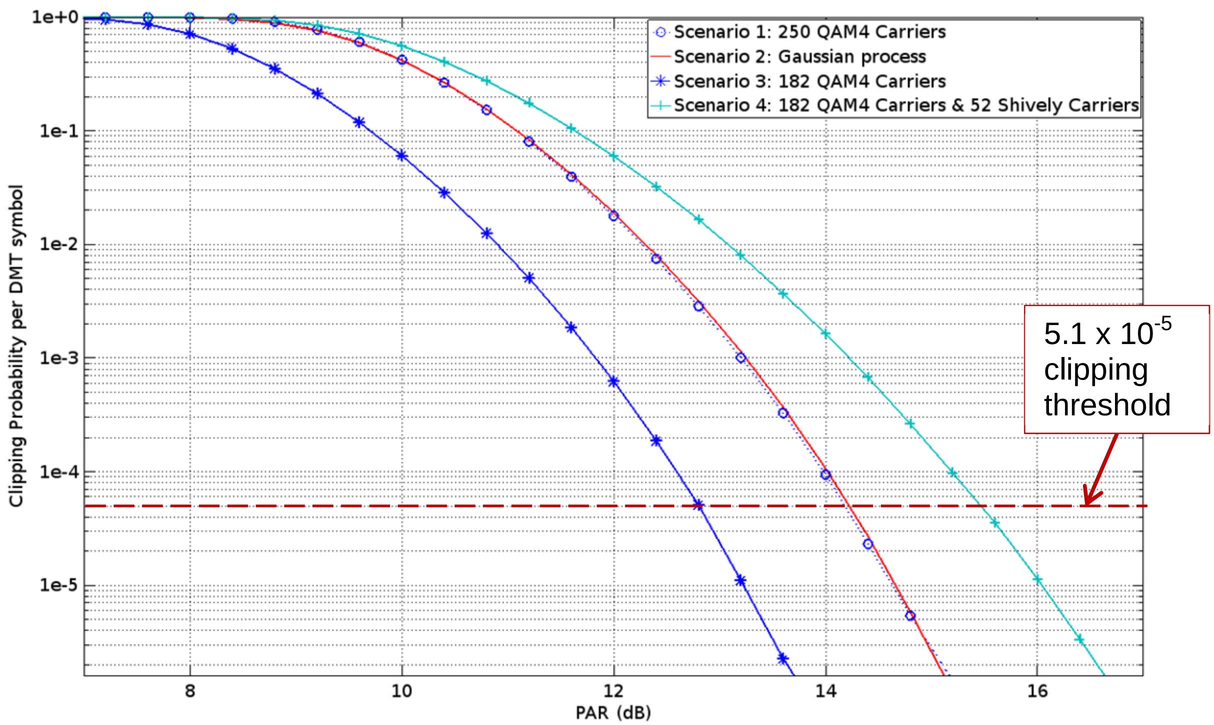
operating on a 12,000 AWG26 cable with no crosstalk, and the attenuation curve shown in Ex. 2009, p. 31, Fig. 6 (as discussed above).

- Scenario #4: A Shively 12,000 foot scenario simulates an ADSL transmitter employing QAM-4 modulation of random data on 182 carriers, and using Shively's bit-spreading technique to transmit an additional 13 bits of random data spread across 52 additional carriers (in 13 groups of 4 carriers each). Because 234 out of 250 carriers (182 + 52) carry data, the transmitter is operating on close to full average power. This scenario simulates the operating conditions of an ADSL transmitter employing Shively's technique on a 12,000 AWG26 line with no crosstalk, and the attenuation curve shown in Ex. 2009, p. 31, Fig. 6 (as discussed above).

48. In reading the graph, consideration must be made to the difference between the clipping requirement of the ANSI T1.413-1995 standard (which is 10^{-7} applied to the samples of the time domain signal, *see* ANSI T1.413-1995, p. 48) and the clipping probability shown in the graph (which reflects the probability of clipping a DMT symbol). For each DMT symbol, the transmitter's inverse fast-Fourier transform (IFFT) will produce 512 time domain samples,[5] so the ANSI T1.413-1995 standard corresponds approximately to a DMT symbol clipping rate of $512 \times 10^{-7} = 5.1\times10^{-5}$. I have annotated a line on the graph at that clipping rate.

[5] This represents the *minimum* sampling rate, also called the Nyquist rate.

Graph 2



49. The simulation shows that for a transmitter to transmit data on all 250 carriers (Scenario #1) with a DMT symbol clipping rate of 5.1 x 10^{-5}, the transmitter must be designed to handle a PAR of approximately 14.2 dB. The impact of Shively's bit-spreading technique can be observed by comparing Scenario #3 (which does not use it) to Scenario #4 (which uses Shively's bit-spreading technique, but is otherwise equivalent to Scenario #3). If only 182 carriers carry data (Scenario #3), then PAR is approximately 12.9 dB. But when Shively's technique is applied to the 52 of the impaired carriers grouped into groups of 4 (Scenario #4), PAR increases to approximately 15.5 dB. This increase in PAR is significant, and a POSITA in the 1990s would have considered a PAR

increase of 2.6 dB relative to *not* using Shively's technique to be very large (approximately 82%). That means that a transmitter requires 82% more power to handle Scenario #4 than to handle Scenario #3, which would increase the transmitter's component cost, power consumption, and waste heat generation.

50. The significance can further be appreciated by comparing Scenario #4 to Scenario #1. Scenario #1 corresponds to transmitting random data on 250 carriers. The difference in PAR values is 15.5 – 14.2 = 1.3 dB, which represents an increase of approximately 35%. That means that a transmitter designed to handle this scenario would have to handle 35% more power, which would increase the transmitter's component cost, power consumption, and waste heat generation. Furthermore, if a transmitter designed to handle the signal of Scenario #1 (i.e., an ordinary ADSL transmitter able to handle a PAR of 14.2 dB without clipping) were presented with the signal of Scenario #4, such a transmitter would have a clipping rate of approximately 10^{-3}. That clipping rate is roughly two orders of magnitude greater than the maximum permitted DMT symbol clipping rate of 5.1×10^{-5}, and would correspond to a clipping event occurring, on average, approximately 4 times per second. Thus, a transmitter designed to handle an ordinary ADSL transmission would not meet the clipping requirement of ANSI T1.413-1995 when presented with a signal employing Shively's technique under the conditions of Scenario #4 (e.g., line length, wire gauge, noise levels, etc.).

51. To be clear, the presented analysis for Scenario #4 is specific to an AWG26 line of approximately 12,000 with no crosstalk noise. Other scenarios, which might consider other line lengths and potential crosstalk or other noise sources, would present conditions in which the impact of Shively's bit-spreading technique would be even worse.

52. Thus a correct analysis of Shively's bit-spreading technique confirms what a POSITA would have intuitively recognized without performing mathematical calculations: Shively's bit-spreading technique significantly increases PAR.

VIII. A POSITA would have wanted to reduce to cost of a transmitter employing Shively's bit-spreading technique

53. I previously opined that "Market forces would have motivated a POSITA to use the data transmission techniques described by Shively and Stopler to provide high-speed Internet access and video services in order to meet demands of consumers for such services." Ex. 1009, ¶80.

54. Shively's bit-spreading technique increases data transmission rate by transmitting more bits in each DMT symbol. Increasing the data transmission rate was considered desirable by telecommunications companies and their customers. However, Shively's bit-spreading technique also increases PAR. Designing a transmitter to handle an increase in PAR leads to a transmitter with a higher component cost, more power consumption, and greater waste heat generation.

through column 12, lines 18 to 36, is to QAM symbols. Thus, when Stopler states that "the phase scrambler is applied to all symbols" (Ex. 1012, 12:26-27), it is describing the phase scrambling of QAM symbols.

57. Second, Stopler explicitly states that the purpose of the phase scrambler is to "randomize the overhead channel symbols" (Ex. 1012, 12:24), which a POSITA would have understood as a reference to the fact that Stopler's overhead channel symbols are non-random, and therefore they suffer from an increased likelihood of being phase-aligned. Since overhead channel symbols are generally QAM symbols in a DMT system, the only way to randomize the overhead channel symbols is to randomize the QAM symbols. Applying phase randomization to DMT symbols, as TQ Delta and Dr. Short interpret Stopler, would not break up any structure or phase alignment of the overhead channel symbols, and thus would not randomize the overhead channel symbols. The interpretation by TQ Delta and Dr. Short would not achieve Stopler's stated purpose for the phase scrambler.

58. Third, Stopler states that the phase scrambler could be followed by a CDMA modulator. Ex. 1012, 12:55-57. CDMA does not use DMT symbols, and therefore it would make no sense for the phase scrambler to be operating on a DMT symbol that is not used by CDMA. In contrast, CDMA does employ QAM symbols. Thus, the only logically and technically coherent reading of Stopler's

description is that Stopler's phase scrambler applies a pseudorandomly selected phase rotation on a QAM symbol-by-QAM symbol basis. This is the natural interpretation of Stopler's description of the phase scrambler that a POSITA would have had.

X. Stopler does not require diagonalization

59. I understand that Dr. Short has opined that a POSITA would not have combined Shively and Stopler because Stopler's diagonalization technique would cause an unacceptable amount of latency in Shively's communication system. I disagree.

60. First, Dr. Short's opinion was based on the incorrect premise that the combination of Shively and Stopler would necessarily employ diagonalization. Stopler makes statements like "regardless of whether diagonalization is being used." Ex. 1012, 10:17. Thus, Stopler considers diagonalization to be optional. Notably, diagonalization is not required for Stopler's phase scrambler to operate. Accordingly, Stopler's description of diagonalization is not relevant to the combination of Shively and Stopler.

61. Second, Stopler describes how the slope of his diagonalization technique can be selected to adjust the amount of latency that it causes. Stopler states that "[o]ther slopes may be used" and advises "taking into account trade-offs between latency and noise immunity." Ex. 1012, 8:35 & 12:47-48. Thus, even if

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CISCO SYSTEMS, INC.,)
) Case No.
Petitioner,) IPR2016-01020
) -and-
vs.) Case No.
) IPR2016-01021
TQ DELTA, LLC,)
) U.S. Patent No.
Patent Owner.) 9,014,243

The deposition of ROBERT T. SHORT, Ph.D., called as a witness for examination, taken before VICTORIA C. CHRISTIANSEN, a Certified Shorthand Reporter of the State of Illinois, CSR No. 84-3192, at Suite 3500, 500 West Madison Street, Chicago, Illinois, on the 27th day of April, A.D. 2017, at 9:17 a.m.

which -- which helps linearize the transmitter system. So those are things I can think of right off.

Q. When you talk about changing the phase of the symbols that are scattered through the band, what do you mean?

A. Well, in a multicarrier system, the primary contributor to peak-to-average occurs when the symbols all have the same -- all have the same value, and if you just change the value, which usually you do by changing -- just by rotating the symbols, then you can reduce the peak-to-average ratio.

Q. Is that something that you're familiar with?

A. Yes.

Q. And is that something that you've done in your -- in your work as a consultant?

A. Yes.

Q. About how many times?

A. I'm not sure I know -- I'm not sure I remember. I can think of three systems where we -- where we did that.

Q. Okay. And what kind of systems were

A. Ask the question again.

BY MR. EMERSON:

Q. Okay. Do you see in this paragraph where they talk about symbols, for example, A1, A2, B1, B2, et cetera?

A. Yes.

Q. Can those be QAM symbols?

A. Yes, I think that's correct.

Q. Okay. Let's go to your -- the declaration now.

A. Okay.

Q. All right. Would you turn to Paragraph 44, please?

A. Okay.

Q. And there you're talking about Shively discussing long loop systems where the cable length is at least 18,000 feet, right?

A. Right. I'm -- I'm quoting Shively here.

Q. Understood. Shively's technique could be used with shorter cable lengths, couldn't it?

A. I don't see any reason to -- he never taught that, he never even mentioned that it could be, so I don't see any reason to make that conclusion.

Q. And my question isn't whether there's a reason to do it or not; my question is this: Could you use Shively's bit-spreading technique on a system having a cable length less than 18,000 feet?

A. I haven't really done that analysis just because he very specifically says that it works at 18,000 feet or more loops. I didn't -- I didn't try to analyze that situation.

Q. So do you have any opinion at all on whether Shively's technique could be used on a system with a cable length of less than 18,000 feet?

A. Not without making the proper analysis. I did not do that analysis.

Q. So it is not your opinion that it would not be possible to use Shively's technique on a shorter cable length?

A. There are a lot of negatives in that. Would you repeat that question?

Q. Sure. You are not expressing an opinion that Shively cannot be used with cable lengths less than 18,000 feet?

A. I will express an opinion that that isn't a useful thing to do, but I -- other than

the signal is too low compared to the noise?

A. That's a good definition of "impairment."

Q. So using that definition, would you agree with me that there are other kinds of impairments that can affect communication systems?

A. Yes.

Q. So since we're talking about signal and noise, noise can be a problem leading to impairment in a communication system, right?

A. True.

Q. True. Near-end crosstalk can be an impairment in a communication system, right?

A. In these types of communication systems, yes.

Q. Because that increases the noise, right?

A. Correct.

Q. Increasing the noise decreases the signal-to-noise ratio?

A. Correct.

Q. Which is an impairment?

A. Correct.

Q. Okay. Likewise, far-end crosstalk can be an impairment, right?

A. Correct.
Q. Because that increases the noise, right?
A. Correct.
Q. And that decreases the signal-to-noise ratio?
A. Correct.
Q. Now, these same issues can affect communication systems where the cable length is less than hundred -- or 18,000 feet, correct?
A. Correct.
Q. It can apply to any kind of communication system?
A. Near-end and far-end crosstalk don't appear in any kind of communication system.
Q. Fair enough. You're right.
Problems associated with increasing noise levels can be a problem with any kind of communication system, right?
A. Correct.
Q. Because signal-to-noise ratios are always an issue, right?
A. Correct.
Q. And you want -- it's best to have a higher -- it's better to have a higher

threshold, correct?
A. Correct.
Q. And the figure on Page 29 of your declaration talks about a 1-bit threshold, right?
A. Correct.
Q. And I'm just wondering: Why did you change that?
A. Well, because Shively talks about transmitting a single bit.
Q. So you did that to make it consistent with Shively?
A. Correct.
Q. Okay. So using the figure in Exhibit 1021 for a 12,000-foot loop, could you do the same calculations that you did for the 18,000-foot loop?
A. I don't know why I would because Shively talks about 18,000-foot curves, but I could do similar calculations.
Q. Okay. So that -- and that was my question, whether you could and not whether in your opinion someone would, okay?
So just to be clear, could you do the same calculations for a 12,000-foot loop?
A. I see no reason why not.

together such that there's a high peak, right?
A. That is a fundamental cause of high peak-to-average.
Q. Right.
A. Pardon me. I don't generally like acronyms, so I will say "peak-to-average."
Q. Now, if -- and when I say "PAR," you understand that to mean the same thing, right?
A. I do.
Q. Okay.
A. Yes.
Q. So fair enough. I understand what you mean and you understand what I mean, right?
A. Correct.
Q. So you would agree with me, right, that one way that an engineer could address high PAR in a communication system would be to use transceiver components that could handle higher peak transmission values?
A. Correct.
Q. And a problem with that, though, is that those components can be expensive, right?
A. Expensive, power hungry. There's -- there's a variety of things that could be a

problem, but yes.
Q. Okay. So you mentioned those components can be expensive, right?
A. Correct.
Q. And they could be power hungry?
A. Correct.
Q. What -- and those are problems, right, issues?
A. Those are issues, yeah.
Q. What other issues do you see with using components -- you said that there were several, so we talked about expense, power.
What other issues are there associated with using equipment that can handle higher transmission values?
A. Just simple component size could be an issue, so...
Q. Which could make the equipment larger?
A. Correct.
Q. What else?
A. I'm not thinking of any others at the moment.
Q. So given those issues, would you agree with me that, you know, system designers or

engineers would be interested in using techniques that could reduce PAR?

A. Correct.

Q. And these problems associated with high PAR were known before 1999, right?

MR. McANDREWS: Objection, foundation.

BY THE WITNESS:

A. That's a way general question.

BY MR. EMERSON:

Q. Okay.

A. In what con- -- in what context?

Q. How about in ADSL.

A. ADSL. I actually don't know the answer to that question. I -- certainly nothing on the record suggests that the problem was known at -- in the context of ADSL, at least not that I recall seeing, and in my own experience, I don't -- I don't remember whether we were worried about that.

Q. And by "that," we mean high peak-to-average?

A. Correct.

Q. Okay. What about in other contexts? Were you aware of that being an issue, high peak-to-average, in other communication contexts?

that it wasn't an issue in multicarrier systems before 1999?

A. I'm telling you I don't remember, correct.

Q. All right. Let's turn to Page 10 of your declaration and I'm going to look at Paragraph 22.

A. Okay.

Q. And in the first sentence, you state, "A high PAR can occur when a large number (or percentage) of the carriers have the same phase."

Do you see that?

A. Correct.

Q. What do you -- what do you mean exactly by a large number or a large percentage?

A. That's a very relative thing. The more of the carriers that have the same phase, the greater the peak-to-average in the -- in that -- the -- yeah, the greater the peak-to-average in that waveform.

So it's a relative thing. If half of them have the same phase and the others don't have the same phase, then you'll have a certain peak-to-average. If you double the number of

carriers that have the same phase, then the peak-to-average will increase.

Q. All right. And so to reduce the number of carriers having the same phase, one way to address that is to randomize the phases of individual carriers within a multicarrier system, right?

A. Yes.

Q. And would you agree with me that this concept of randomizing the phases of individual carriers within a multicarrier signal to reduce PAR was known in the prior art?

A. I don't know that.

Q. You don't know that.

A. I don't know that.

Q. Was that -- was this idea of randomization known in your experience before 1999?

A. I don't know that.

Q. You don't know that?

A. I don't know that.

Q. You don't know that. Okay.

It's not your opinion that it wasn't known, though, correct?

A. I see nothing in the record or in my

may be the same as that used in ADSL. In order to randomize the overhead channel symbols, a phase scrambling sequence is applied to the output symbols."

Randomizing the overhead channel symbols was a known thing at this time, I remember that, but what you're doing is randomizing in time, not frequency, because the channel -- the known channel symbols, you know, are adjacent in time, and so the only thing that he's saying is that you're trying to randomize in time by virtue of the fact that he's trying to randomize the overhead channel symbols.

So there's -- there's no reason in this case to randomize in frequency, as well. There's no reason based on his rationale here.

Q. Okay. At the beginning of that paragraph, Stopler states, "The input to the QAM mapper is data in the form of m-tuples which are to be mapped into QAM symbols, for example, ranging from QPSK to 256-QAM, tone by tone."

Do you see that?

A. I do.

Q. Okay. And when they're talking about

symbols there, they're talking about QAM symbols, right?

A. Correct.

Q. Okay. Pilot tones are overhead symbols, right?

A. Pilot tones would be a form of overhead, yes.

Q. And are there other kinds of overhead symbols?

A. I don't know.

Q. You don't know one way or the other?

A. I don't know.

Q. Okay. And pilot tones are QAM modulated, right?

A. Typically. You know, I don't remember the ADSL standard specifically. They're a known -- a known -- they're a symbol at a known phase, but QAM would be a good way to do that, yes.

Q. Okay. And when Stopler talks about overhead channel symbols, he's referring to QAM symbols, right?

A. I believe that's right. Yeah, I don't believe he says, but that -- I think that's a reasonable discussion point.

A. No, that -- that does not.
Q. Okay.
A. In fact, it's really kind of irrelevant to the rest of this discussion. It's just a mechanism for doing scrambling.
Q. Well, so -- but you agree QAM symbols are input to the phase scrambler?
A. One or more QAM symbols are.
Q. Now, does Stopler state anywhere that a phase scrambler groups multiple QAM symbols into a DMT symbol?
A. I don't believe he says that.
Q. So what's the output of the phase scrambler?
A. The output for the phase scrambler is the input rotated by whatever the phase scrambling algorithm is.
Q. Okay. And those would be QAM symbols?
A. It would be -- in the case of CDMA, it would be a QAM symbol. In the case of OFDM -- I'll use OFDM generally rather than DMT --
Q. Okay.
A. -- but with OFDM, it would be the bank. It would be -- based on what he's saying, it would

be the bank, the entire OFDM symbol.
Q. When you say "based on what he's saying," what are you referring to in particular?
A. I'm referring specifically to the statement that he's randomizing the overhead channel symbols. It would make no -- it would not be valuable to randomize the overhead channel, and follow that by -- let me find the line.
"However, to simplify implementation, the phase scrambler is applied to all symbols," not just the overhead symbols, so he is implying that he's rotating the entire bank of symbols.
Simplicity would not drive you to scramble individual subcarriers one by one. You'd want to -- based on what he's saying, oversimplification in doing the -- the pilot symbols, the overhead symbols, you'd do the whole bank. There would be no reason to do anything else.
Q. But that's something you are concluding from this?
A. It's something I'm concluding from this.
Q. It's not something that Stopler tells us?

A. Stopler is not clear. Stopler does not teach anything but what I said. He does teach what I said.
Q. Well, Stopler -- Stopler doesn't teach applying the phase scrambler to the DMT as a whole, correct?
A. I think he does, but --
Q. Not expressly.
A. I will -- I will say that it's somewhat ambiguous.
Q. Well, you would agree with me that he doesn't expressly teach applying the phase scrambler to the DMT as a whole?
A. I would agree with that.
Q. In that sentence, however, to simplify what you read --
A. Yes.
Q. -- it says it applies to all symbols, right?
A. Correct.
Q. And those symbols are QAM symbols?
A. Correct.
Q. And the only dispute is whether they're done individually or to the entire DMT?

Q. In Shively, the DSL receiver will compute the signal-to-noise ratio on a per-tone basis, right?
A. Shively assumes that that's known, so okay, yes.
Q. So that's a yes?
A. Yeah, that's a yes.
Q. Okay. Let's turn back to your declaration and let's go to Paragraph 77.
A. Okay.
Q. Just in general, would you agree that within the field, the meaning of -- when we're talking about "rotating," we're talking about changing the phase of the carrier?
A. I didn't get -- hear the question.
Q. Well --
A. Maybe I just misunderstood it.
Q. Sure. We talk about -- we talk about rotation in this context, right?
A. Correct.
Q. All right. And, in fact, in Paragraph 77, you talk about phase rotation, right, or at least you quote some -- a question that refers to phase rotation, correct?

A. Correct.
Q. When we talk about phase rotation, we're talking about changing the phase of a carrier, right?
A. Correct.
Q. Okay. And phase rotation and phase scrambling are referring essentially to the same thing, right?
A. Not necessarily.
Q. How would they be different?
A. A phase rotation -- phase scrambling would tend to be somewhat of a pseudo-random thing -- in other words, somewhat unpredictable -- where phase rotation would be totally predictable. It may not have the same connotation at all.
Q. Okay. So when we're doing -- when we're referring to "phase scrambling," we're doing phase rotation on a pseudo-random basis?
A. That -- that's a reasonable thing to do, yes.
Q. Okay.
A. I want to be careful not to make -- say that that's the only thing, but it's -- it's a reasonable thing.

tone is a tone that's impaired because its signal has been dropped for some reason such as attenuation.

A. Okay.

Q. All right? And by a noise-impaired tone, I mean a tone that's impaired because you've got more noise in the channel.

A. Okay. I mean, that's not the way Shively describes it, but that -- I can agree with what you're saying.

Q. Well, Shively doesn't limit impairment to attenuation-related impairment, does it?

A. Well, he -- his entire concept is -- is a sloped attenuation model, if you will, so the attenuation is decreasing at some slope -- some monotonic slope, and that is -- I would infer that to mean it's a -- it's a signal -- it's the signal falling below the noise floor rather than the noise magically getting bigger.

Q. Okay. But his technique is not limited to those situations where the impairment is caused by a decrease in signal rather than increasing noise, is it?

A. I would think you could apply his

technique elsewhere, but I don't believe he teaches such a thing.

Q. Understood. But you -- you would agree that you could use his technique on other kinds of impaired tones?

A. Okay, yes.

Q. You would agree with that?

A. I agree with that.

Q. Okay.

MR. KARP: Telephone people, please put your phones on mute. Thanks.

BY MR. EMERSON:

Q. Let's go to your declaration, please.

A. Okay.

Q. All right. Let's go to Page 11.

A. Okay.

Q. And you see you have a figure there on the top of Page 11?

A. Yes.

Q. On the right side of that figure, you have a graph that represents the sum of these 25 carriers?

A. Correct.

Q. That's a multicarrier signal, right?

ADSL Modulation

Although CAP modulation is well-understood and relatively inexpensive, some argue that it is difficult to scale because it is a single-carrier modulation technique and is susceptible to narrowband interference. DMT uses multiple carriers and is standardized by the ANSI committee T1E1.4 (document T1.413) and ITU G.992.1, or G.dmt.

This standard calls for 256 subbands of 4 kHz each, thereby occupying 1.024 GHz. Each subband can be modulated with QAM 64 for clean subbands, down to QPSK. If each of the subbands can support QAM-64 modulation, then the forward channel supports 6.1 Mbps. On the return path are 32 subbands, with a potential for 1.5 Mbps.

CAP and DMT Compared

CAP is a single-carrier technique that uses a wide passband. DMT is a multiple-carrier technique that uses many narrowband passbands as individual carriers. The two have a number of engineering differences, even though they ultimately can offer similar service to the network layers discussed previously.

Adaptive Equalization

Adaptive equalizers are amplifiers that shape frequency response to compensate for attenuation and phase error. Adaptive equalization requires that the modems learn line characteristics—and do so by sending probes and looking at the return signals. The equalizer then knows how it must amplify signals to get a nice flat frequency response. The greater the dynamic range, the more complex the equalization. ADSL requires 50 dB of dynamic range, making adaptive equalization complicated. Only with recent advances in digital signal processing (number crunching) has it become possible to have such equalization in relatively small packaging.

Adaptive equalization is required for CAP because noise characteristics vary significantly across the frequency passband. Adaptive equalization is not needed for DMT because noise characteristics do not vary across any given 4 kHz subband. A major issue in comparing DMT with CAP is determining the point at which the complexity of adaptive equalization surpasses the complexity of DMT's multiple Fourier transform calculations. This is determined by further implementation experience.

Power Consumption

Although DMT clearly scales to RBB and does not need adaptive equalization, other factors must be considered. First, with 256 channels, DMT has a disadvantage regarding power consumption (and, therefore, cost) when compared with CAP. DMT has a high peak to average power ratio because the multiple carriers can constructively interfere to yield a strong signal. DMT has higher computational requirements, resulting in more transistor in the transceiver chips. Numbers are mostly proprietary at this point, but it is estimated that a single transceiver

will consume 5 watts of power, even with further advances. Power consumption is important because hundreds or thousands (as carriers dearly hope) of transceivers might be at the CO. This would require much more heat dissipation than CAP requires.

Speed

DMT appears to have the speed advantage over CAP. Because narrow carriers have relatively few equalization problems, more aggressive modulation techniques can be used on each channel. For CAP to achieve comparable bit rates, it might be necessary to use more bandwidth, far above 1 MHz. This creates new problems associated with high frequencies on wires and would reduce CAP's current advantage in power consumption.

Licensing

DMT is a public, open standard. Globespan Technologies (formerly ATT Paradyne) is the licensing agent for CAP. As of this writing, 20 companies have been issued licenses. Among the licensees are Bellcore, Westell, Nokia (Finland), and NEC (Japan). One of the marketing difficulties of CAP is that system providers are reluctant to license the intellectual property from a single source; it makes them feel vulnerable. If there were more licensors of the technology, perhaps CAP would have fared better.

Overview of CAP Versus DMT Summary

This discussion has tried to fairly represent the CAP/DMT debate. Without a doubt, advances will be made in both technologies, which will narrow the various technical gaps. Table 4-3 summarizes the important differences as they exist at the time of this writing.

Table 4-3 *Comparison of CAP and DMT for ADSL*

	CAP	**DMT**
Power consumption	Lower, fewer gates	Higher peak/average, but will likely narrow gap
Forward carriers	1	256
Return carriers	1	32
Increment	320 Kb	32 Kb
Adaptive equalizers	Needed	None
Licensing	Globespan	Many sources
Standardization	In process	ITU and ANSI
Key competitors	Globespan, Paradyne, Westell	Conexant, Cisco, Alcatel, Amati (now Texas Instruments), Westell, Efficient Networks

DMT Signals with Low Peak-to-Average Power Ratio

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Abstract

This contribution proposes a new family of methods to reduce the Peak-to-Average power Ratio (PAR) in Discrete Multi-Tone (DMT) and Orthogonal Frequency Division Multiplexing (OFDM) systems. This method avoids an use of extra Inverse Fast Fourier Transformations (IFFTs) as was done in some previously published techniques, but instead is based on transformations in the time domain of the original sequence available at the output of the IFFT processor. The improved statistics of peak power in the optimized transmit signal are demonstrated by simulation results.

1. Introduction

Multi-carrier modulation has recently being used for many applications such as high-speed voice band modems and digital subscriber line systems (xDSL). These systems use DMT over wire media and OFDM for wireless communication.

The amplitude distribution of a DMT signal with random input data is approximately Gaussian for large number of carriers. Therefore the DMT signal will occasionally present very high peaks. These peaks require a high dynamic range of the ADC (analog to digital converter) and analog front end in absence of any clipping or peak reduction technique. This would result in inefficient amplifiers (with excessive power dissipation) and expensive transceivers.

Recently, there has been a variety of proposed methods to reduce PAR [2]-[6], but none of these methods is able to achieve simultaneously a large reduction in PAR with low complexity, without performing an extra IFFT calculations, without loss in data rate, without increase in the transmitter average power and without decrease in the minimum distance or equivalently without loss in the noise margin

This paper proposes a new technique based on [1], which can achieve all these goals.

2. The Proposed Method to reduce PAR

The basic characteristic of DMT is that the data are modulated on N QAM subcarriers X_k $(k = 0,1,\ldots,N-1)$ each of equal bandwidth. This frequency multiplexing can easily be implemented by using an Inverse Fast Fourier Transform (IFFT) in the modulator that transforms the subcarrier vector $\mathbf{X} = [X_0, X_1, \ldots, X_{N-1}]^t$, with $X_i = X^*_{N-i+2}$ for $i = 2,\ldots,N/2$ and t denotes the transpose and * the complex conjugate, into the time domain. This results in the discrete time representation $\mathbf{x} = [x_0, x_1, \ldots, x_{N-1}]^t$ with

$$x_n = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k e^{j\frac{2\pi}{N}kn} \qquad n = 0,1,\ldots,N-1 \tag{1}$$

The sequence $\mathbf{x}$ is real and is often referred to as a DMT symbol. It's well known that for large N, the output time vector distribution can be well approximated by a Gaussian distribution and has a relatively large PAR defined as:

$$PAR(\mathbf{x}) = \frac{|x_{\max}|^2}{\sigma_x^2} \tag{2}$$

where $x_{\max}$ and σ_x are respectively the maximum value of x_n and the root-mean square value of $\mathbf{x}$ over all possible symbols.

The real sequence given by Eq. (1) can also be obtained by using a complex IFFT of the modulated carriers which are organized in the form of the following complex sequence $Y(n)$:

$$Y(n) = \begin{cases} \dfrac{X(n)}{2} & \text{for } n = 0, \dfrac{N}{2} \\ X(n) & \text{for } 0 < n < \dfrac{N}{2} \\ 0 & \text{for } \dfrac{N}{2} < n \le N-1 \end{cases} \tag{3}$$

```
clear all
format compact

M = 4; %repetitions per bit
N = 256; %max number of tones or subcarriers
Zl = 6; %number of low freq zero tones
Zs = 13*M; %number of Shively tones
ZH = 15; %number of unused high freq tones
P = round(Zs/M) %number of repeating bits


K = 3*10^7 %number of DMT symbols to simulate. 1e-6 is 3min, 1e-7 is 30min
PAR = zeros(1,K);
PARz = zeros(1,K); %Zero tones
PARs = zeros(1,K); %Shively
PARg = zeros(1,K);

tic
for k=1:K
    if mod(k,10^6)==0
        k
        toc
        tic
    end

    bits = sign(randn(1,P));
    repeat_bits = kron(bits,ones(1,M));

    X = .707*(sign(randn(1,N-Zl)) + j*sign(randn(1,N-Zl))); %random 4QAM symbols
    X(64-Zl) = 1; %model constant pilot

    Xz = X;
    Xz(end-Zs-ZH+1:end)=0;
    Xs = Xz;
    Xs(end-Zs-ZH+1:end-ZH)=repeat_bits;


    Y  = [zeros(1,Zl),  X, 0, fliplr(conj(X )), zeros(1,Zl-1)];
    Yz = [zeros(1,Zl), Xz, 0, fliplr(conj(Xz)), zeros(1,Zl-1)];
    Ys = [zeros(1,Zl), Xs, 0, fliplr(conj(Xs)), zeros(1,Zl-1)];
    y  = ifft(Y);
    yz = ifft(Yz);
    ys = ifft(Ys);

    Ave = (y*y')/length(y);

    Peak = max(y.*y);
    Peakz = max(yz.*yz);
    Peaks = max(ys.*ys);


    PAR(k)  = 10*log10(Peak);    %PAR for 4QAM IFFT output
    PARz(k) = 10*log10(Peakz);    %PAR for 4QAM IFFT output with zero tones
    PARs(k) = 10*log10(Peaks);    %PAR for 4QAM IFFT output with Shively tones
    PARg(k) = 10*log10(max(randn(1,2*N).^2)); %PAR of a Gaussian symbol with 2*N points

end
```

```
PAR  = real(PAR + 10*log10(2*N)); %normalize to correct for Matlab IFFT power loss of 2N
PARz = real(PARz + 10*log10(2*N));
PARs = real(PARs + 10*log10(2*N));
PARg = real(PARg + 10*log10((N-Zl)/N)); %normalize Guassian power to N-Zl tones out of N


Axis = 6:0.4:20;

Np = hist(PAR,Axis);
Ng = hist(PARg,Axis);
Nz = hist(PARz,Axis);
Ns = hist(PARs,Axis);

figure(2)
semilogy(Axis,1-cumsum(Np)/K,':o','LineWidth',2,'MarkerSize',9,Axis,1-
cumsum(Ng)/K,'r-','LineWidth',2,'MarkerSize',10,Axis,1-cumsum(Nz)/K,'b-*',
'MarkerSize',12,'LineWidth',2,Axis,1-cumsum(Ns)/K,'-+',
'LineWidth',2,'MarkerSize',10)
set(gca,'fontsize',18)
xlabel('PAR (dB)','fontsize',18)
ylabel('Clipping Probability per DMT symbol','fontsize',18)
leg = legend('Scenario 1: 250 QAM4 Carriers','Scenario 2: Gaussian process',
'Scenario 3: 182 QAM4 Carriers',
'Scenario 4: 182 QAM4 Carriers & 52 Shively Carriers')
set(leg,'fontsize',18)
grid on,shg
axis([7 17 32/K 1])
```

A. Yes.
Q. Okay. Can you tell me, does the Shively reference include any discussion of PAR?
A. I don't remember seeing it.
Q. Okay. Does Shively include any explanation that it's spreading invention causes an increase in PAR?
A. I don't remember seeing that.
Q. Does Shively explain anywhere that its spreading invention would cause a PAR problem?
A. I don't remember seeing that.
Q. Okay. So the Shively reference itself does not indicate that its invention creates any issue with PAR; right?
A. I didn't see it.
Q. And when I say "spreading invention," do you understand generally what I'm referring to?
A. Yes. Replicating a bit multiple times on multiple carriers which will increase PAR.
Q. We're going to talk about that in a little more detail in a second here.
MR. McANDREWS: So let's mark the next exhibit here. Actually, I'm going to mark two exhibits. So the first exhibit I'm going to mark is the declaration of Jose Tellado in matter Number

MR. McANDREWS: Sure.
(Off the record.)
BY MR. McANDREWS:
Q. I'm going to shift gears just slightly here. So I want to talk just briefly about pilot tones.
Are you familiar with what a pilot tone is in an ADSL system, for example?
A. The pilot, the concept of pilot tones in multicarrier systems, yes, I know the concept of a pilot tone.
Q. Okay. So in an ADSL system, according to the T1.413 standard, for example, there's a single pilot tone; correct?
A. I don't know that.
Q. You don't know that. Okay.
You don't know whether there's a single pilot tone or multiple pilot tones?
A. I have worked on multiple multicarrier systems. They typically have many pilot tones.
Q. But are you aware of multicarrier systems that have a single pilot tone?
A. I don't know of any that has one. I know of what the carrier systems with many pilot tones.
Q. Okay. And what do you mean by "tone" there?
A. Subcarrier.

Q. Okay. So there's a -- so when I say a single pilot tone, I'm referencing a single subcarrier.
A. Yes.
Q. So there's a subcarrier that carries a pilot.
A. Okay.
Q. Okay.
A. Uh-huh.
Q. And you're saying you're not familiar with any systems that use only a single carrier for the pilot?
A. Well, you just told me one. Now I do.
Q. Well, did you know that? Did you know that?
A. I didn't know that ADSL only had one subcarrier, but that's fine.
Q. Okay.
A. There's many systems with multiple subcarriers that are used for pilot or that have symbols.
Q. Okay. Are you familiar with the technique of scrambling pilot tones from one DMT symbol to the next?
A. Am I familiar with -- say it again.
Q. Okay. So are you familiar with a system in

from one carrier to the next.
A. Uh-huh.
Q. Can you think of a reason why you would be doing that; that is, addressing an issue that exists when you have only a single as opposed to multiple pilot tones?
A. If you had only one pilot and the reason to not send the same value over and over again would be to not create a DC bias.
Q. Okay. And can you explain what a DC bias is?
A. The average -- if you took the average of your modulator output, if the symbols were random, the mean of all those symbols will be zero. If one tone always has a constant in it, that's modulated output would have a mean because one tone is a constant, it's not random.
Q. Okay. Let me ask it this way. Were you aware that in the T1.413 standard --
A. Uh-huh.
Q. -- the single pilot tone was not randomized from one DMT symbol to the next. Were you aware of that?
A. I didn't know that.
Q. Okay. And were you aware that in subsequent

involved in this matter; correct?
A. No.
Q. And you didn't go find it on your own; correct?
A. No. It was given to me.
Q. Okay. And Stopler does not mention peak-to-average power ratio, does it?
A. I did not see it.
Q. Okay. And it doesn't state anywhere that it's addressing a PAR issue; correct?
A. I didn't see that.
Q. And it doesn't say anywhere that its teachings could potentially reduce PAR; correct?
A. I didn't see it.
Q. Okay. Would you be surprised if I told you that the Stopler reference doesn't even mention the word "power"?
A. I didn't see it. I'm not surprised.
Q. Okay. So why was Stopler selected to be combined with Shively?
A. My declaration lists a number of reasons to combine. The first one is it would have been obvious for a POSITA to combine Shively and Stopler because the combination is merely the use of a known technique to provide a similar device, method, or

Q. Okay. Are there other techniques for reducing PAR or reducing problems associated with PAR?

A. Another idea in my thesis is use a bigger constellation alphabet and use points in a bigger constellation space to eliminate the peaks in the time domain, which is a modulator output.

Q. Okay. Can you think of any others?

A. So when I did my thesis, the most popular were phase-scrambling based so those were common. In the back of my thesis, there's many references to prior art that explains how to do phase scrambling to reduce PAR. My thesis is different and it does not use phase scrambling. Phase scrambling was probably the most popular way.

My thesis, I turned it in September 1999 and I did my oral defense late 1998 and I started working early '99. So the content of my thesis and my publications are -- you can look on my CV, but a lot of the paper submittals were done '98 or before that.

Q. Okay. And those papers were describing?

A. My inventions, and they would have in the citation a list to references that used phase scrambling to reduce PAR.

symbols, a phase scrambling sequence is applied to the output symbols."

If they were truly random to start with, why would -- I believe he's concerned about structure and that's why chooses a randomizing of the overhead channel symbols.

Q. But you didn't take into consideration when you interpreted that, that it may be talking about randomizing overhead channels from 1 DMT symbol to the next, did you?

A. The natural interpretation, since Stopler is teaching how to randomize plural overhead channel symbols, the natural interpretation is that each symbol would have a different phase rotation.

Q. So you're suggesting that each symbol from one symbol to the next would have a different phase rotation?

A. No. No. Individual QAM symbols within the same modulation block.

Q. Where does it say that?

A. If you read the paragraph, "The input to the QAM mapper 82" -- we're on column 12, line 21.

"The input to the QAM mapper 82 is data in the form of m-tuples which are to be mapped into QAM symbols" -- basically getting

m-tuples, mapping them to one QAM symbol -- "for example, ranging from QPSK to 256-QAM tone by tone."

So in the context of QAM mapper 82, which is in Figure 5, this block is processing at the QAM symbol by the QAM symbol, so each QAM symbol is processed individually. The constellation mapping may be the same as that used in ADSL. So again, it uses ADSL as an example.

"In order to randomize the overhead channel symbols, a phase scrambling sequence is applied to the output symbols."

It's in the context of QAM mapper 82 mapping m-tuples groups of bits into QAM symbols, one symbol at a time, tone by tone, inserting overhead channel symbols, which are plural, and phase scrambling is applied to these symbols. My interpretation has been applied on a QAM symbol by QAM symbol.

Q. Okay. But your interpretation was without knowledge that at the time pilot tones were being randomized from DMT symbol to DMT symbol; correct?

MR. EMERSON: Form.

THE WITNESS: There are multiple multicarrier systems. You've just given me one example. Stopler's teachings do not apply only to

real individual, but rather a hypothetical individual having the qualities reflected by the factors discussed above.

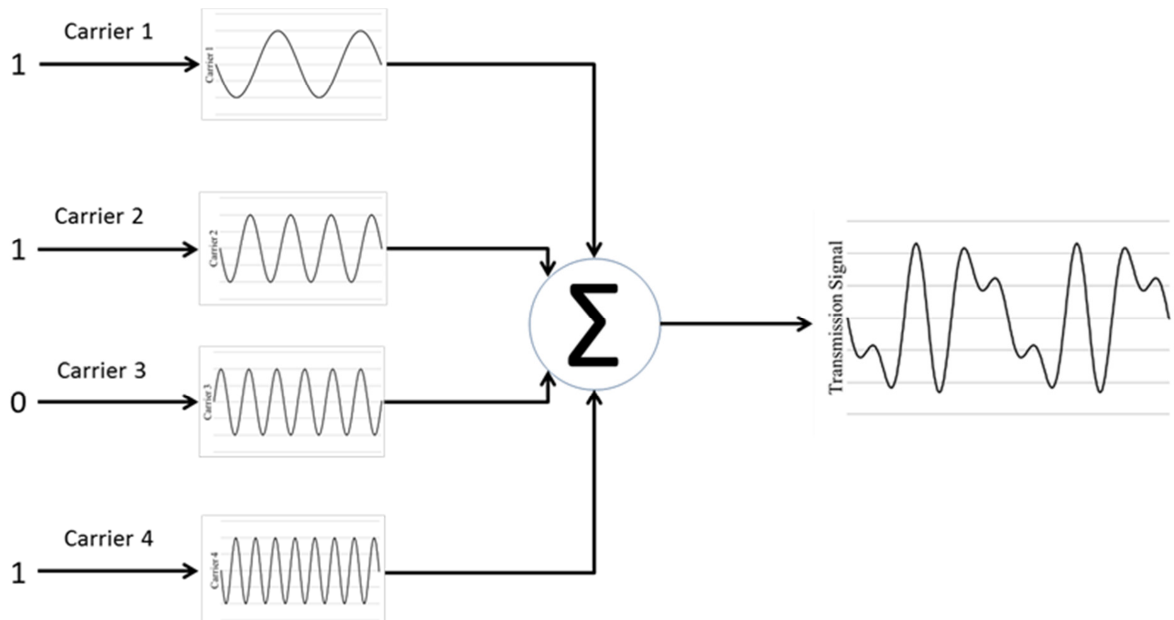
16. For purposes of this declaration only, I have adopted Dr. Tellado's definition of a person of ordinary skill in the art. In particular, Dr. Tellado stated that a person having ordinary skill in the art would have "(i) a Master's degree in Electrical and/or Computer or equivalent training, and (ii) approximately five years of experience working with multicarrier communications systems." Ex. 1009 at ¶ 18. It is through this hypothetical person's eyes that I have reviewed the prior art and the '243 patent.

V. INTRODUCTION TO "MULTICARRIER" COMMUNICATIONS TECHNOLOGY AND PEAK-TO-AVERAGE RATIO ("PAR")

A. Multicarrier Systems

17. The '243 patent discloses a system that communicates using multicarrier signals. Ex. 1001 at 1:26–29. A multicarrier signal includes a number of carrier signals (or carriers) each operating at a different frequency. Each carrier is modulated to encode one or more bits (*i.e.*, "1" or "0"). Each carrier effectively serves as a separate sub-channel for carrying data. The carriers are combined as a group to produce a transmission signal, which is transmitted across a transmission medium (*e.g.*, phone lines, coaxial cable, the air, *etc.*) to a receiver.

18. In an example illustrated below, four carriers—Carrier 1, Carrier 2, Carrier 3, and Carrier 4—are combined simultaneously into one transmission signal.



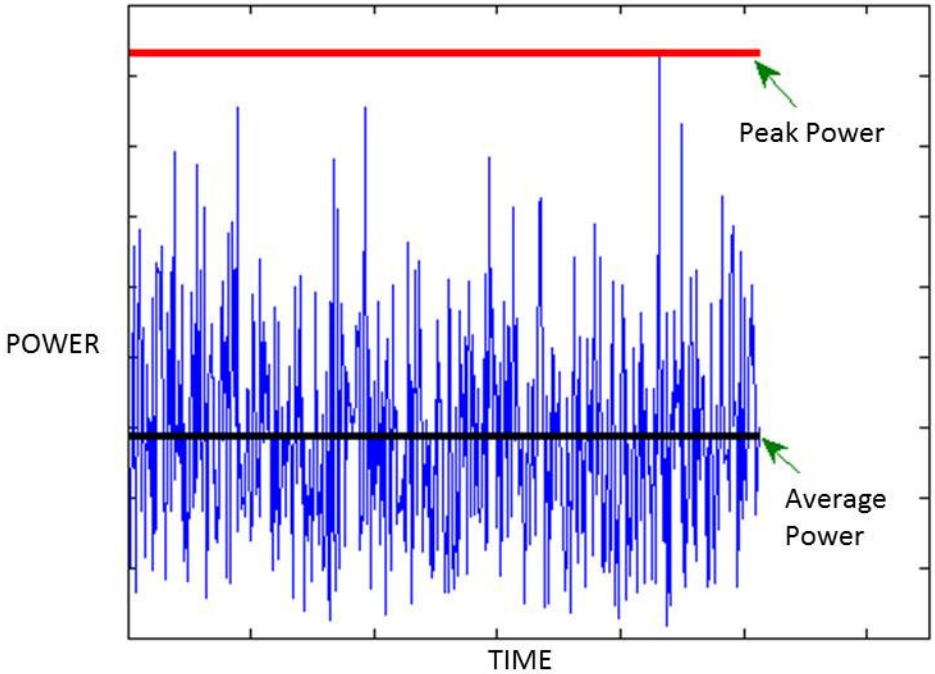
19. Multicarrier systems may use the phase of carriers to encode different bit values. In the example above, a carrier with a phase of zero represents a bit value of “0”; conversely, a carrier with a phase-shift of π (or 180°) represents a bit value of “1”. In this example, Carriers 1, 2, and 4 have a phase-shift of π, and therefore each represent a “1”. Carrier 3 has as phase of zero, and therefore represents a “0”. Together, these four carriers encode input bits having binary values of 1, 1, 0, and 1. This information is transmitted as a single transmission signal—that is, the irregular waveform shown above on the right side of the figure. In practice, a multicarrier transmission signal will typically comprise a

combination of many more than four carriers (*e.g*., hundreds or even thousands of carriers) and in this way can substantially increase the "speed" or data carrying capacity of the system.

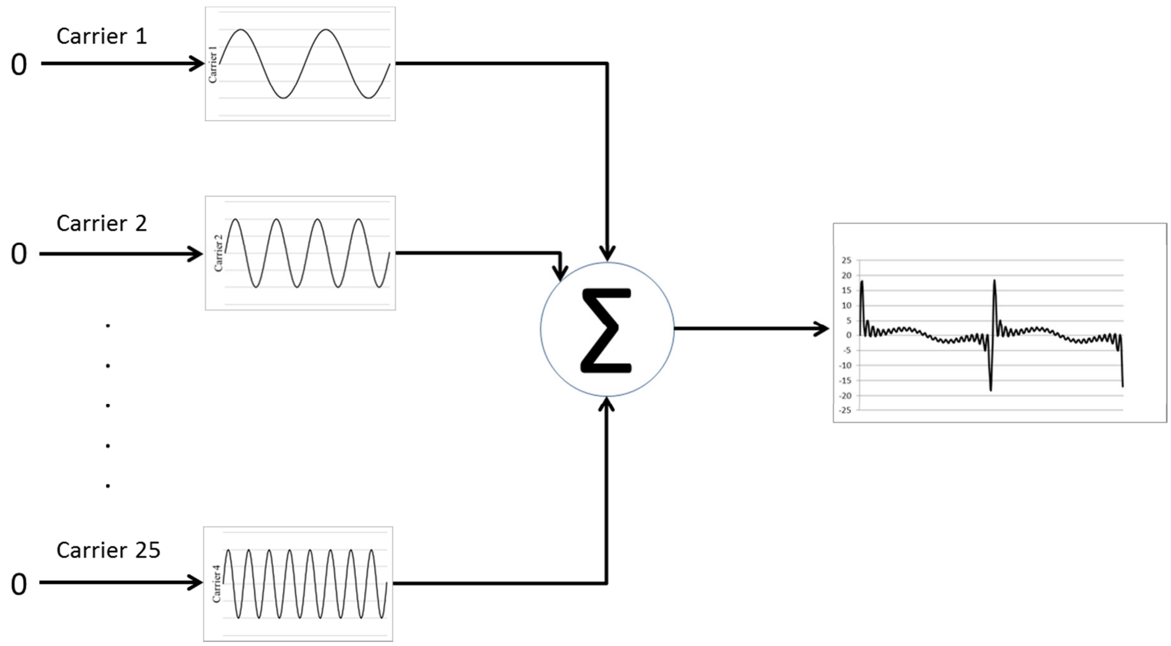
B. Peak-to-Average Power Ratio ("PAR")

20. A multicarrier transmission signal can be characterized by a metric known as "PAR," which stands for peak-to-average ratio or peak-to-average power ratio. Ex. 1001 at 1:60–65. As the '243 patent explains, "The PAR of a transmission signal is the ratio of the instantaneous peak value (i.e., maximum magnitude) of a signal parameter (e.g., voltage, current, phase, frequency, power) to the time-average value of the signal parameter." Id. at 1:65–2:2 (emphasis added). References to PAR herein relate to PAR for the power of a transmission signal.

21. In the following illustration, a signal (blue) has a peak power (red line) and an average power (black line). The ratio of the peak power to the average power of the signal is the PAR.



22. A high PAR can occur when a large number (or percentage) of the carriers have the same phase. The '243 patent recognized that: "If the phase of the modulated carriers [in a transmission signal] is not random, then the PAR can increase greatly." Id. at 2:15–16. The phases of the carriers would not be "random," for example, when the underlying data being modulated is repetitive (e.g., a long string of 0s or a long string of 1s), or where the same data is purposely sent in a redundant manner on multiple carriers. In the example below, all 25 of the carriers have the same phase of zero. Because the carrier signals are "in-phase," their amplitudes will add together to create a transmission signal (illustrated on the right side of the figure below) having large spikes in amplitude and, therefore, a high PAR.

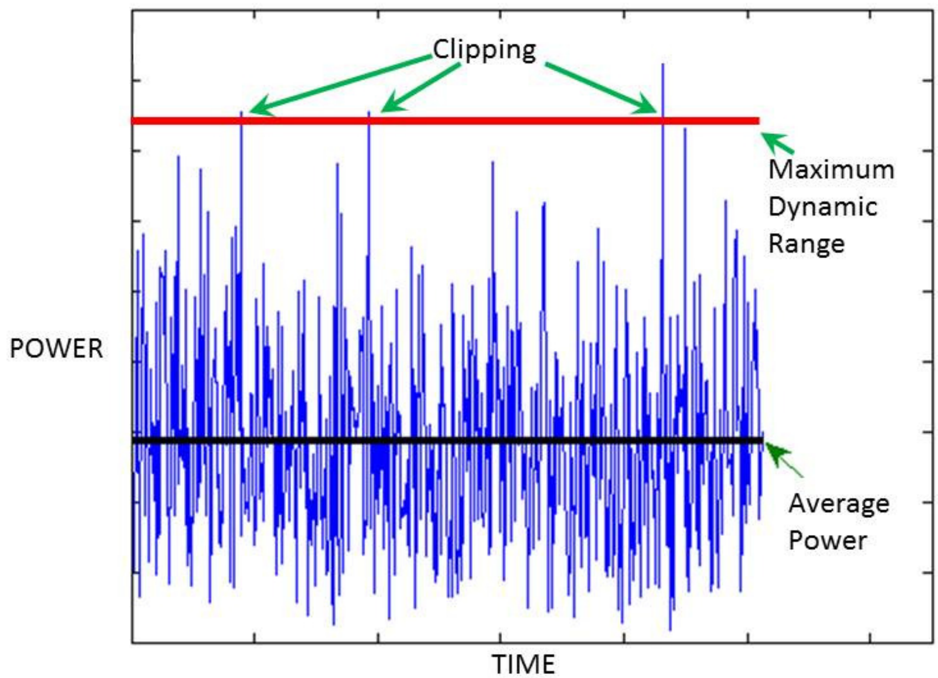


C. PAR "Problem"

23. Because a multicarrier transmission signal is the sum of many carrier signals, the transmission signal is expected to have a significant PAR. Conventional multicarrier systems, therefore, were designed to accommodate PAR. There is only a "problem" with PAR, however, when an undue amount of PAR-induced distortion occurs in a multicarrier transmitter, creating additional errors in the receiver above the normal noise-induced errors.

24. Electronic components in a multicarrier transceiver are ideally designed to process multicarrier signals without distortion. Distortion occurs when a signal exceeds the capacity (or dynamic range) of an electronic component, such as an amplifier, a digital-to-analog converter, or an analog-to-digital converter.

When the maximum dynamic range of a component is exceeded, the signal will become distorted or will "clip."



25. As a result of clipping, the portion of the signal exceeding the component's dynamic range is truncated and the information in the cut off signal portion is lost.

26. One way to reduce clipping is to use transceiver components that have larger dynamic ranges. Such components, however, can be expensive and may consume a relatively large amount of power. Increasing the dynamic ranges of the components, therefore, can be impractical.

27. Instead of demanding ideal circuitry, multicarrier systems are designed to actually allow a certain amount of clipping. One design criterion is

specified as a "clipping rate." One such multicarrier system is digital subscriber line ("DSL"). In DSL at the time of the invention ("ADSL-1995") the maximum allowable clipping rate is one in every 10^7 (ten million) samples, which corresponds to a clipping probability of 10^{-7} (or one in ten million). Ex. 1017 at p. 48, § 6.11.1. This exact clipping probability is also referenced in the '243 patent. *See* Ex. 1001 at 2:6–8.

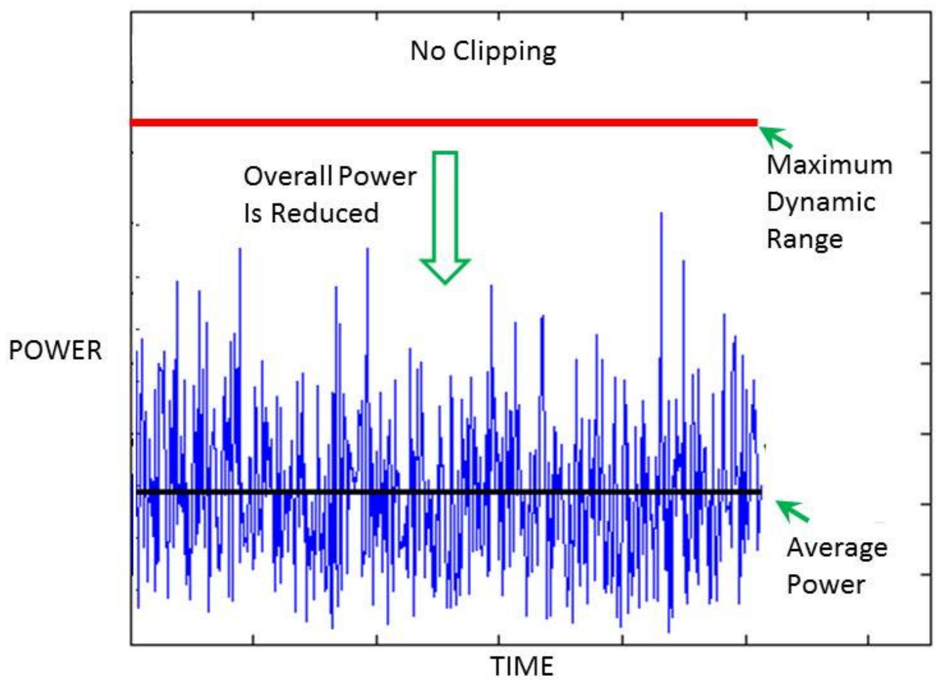
28. DSL is subject technology in the '243 patent (Ex. 1001 at 3:25–26), Shively (Ex. 1011 at 1:4–5), Stopler (Ex. 1012 at 12: 23–24), and Gerszberg (Ex. 1013 at 1:19–26). A particular DSL standard in use at the time of the invention is defined in Exhibit 1017—ANSI standard T1.413-1995 ("ADSL-1995"). The ADSL-1995 standard is described in Shively (Ex. 1011 at 1:51–53 and 2:12–24).

29. In ADSL-1995, the ideal sampling rate is approximately 2.2 million samples/second. Given this sampling rate and a clipping probability of 10^{-7}, there would be a clipping error when processing a transmission signal about once every 4.55 seconds on average. This clipping rate is deemed acceptable because, at this rate, error correction methods are capable of fixing the errors cause by clipping.

30. A PAR "problem" exists when the actual clipping rate exceeds the maximum allowable rate. In the example above, if there is a clipping error once every 3 seconds (on average), then a PAR problem exists—because 3 seconds is less than 4.55 seconds. As the inventor of the '243 patent recognized, "If the phase

of the modulated carriers is not random, then the PAR can increase greatly." Ex. 1001 at 2:15–16. "An increased PAR can result in a system with high power consumption and/or with high probability of clipping the transmission signal." *Id.* at 2:25–27. Contrarily, if the clipping probability does not increase, then there is no PAR problem.

31. One way to decrease the impact of PAR and reduce the probability of clipping is by reducing the overall signal power below the maximum overall signal power for which the system was designed, as depicted below.



32. The system disclosed in Shively is an example of a system in which the overall signal power is reduced below the maximum overall signal power for

which the system was designed. Such power reduction is shown by Shively, and it results in a system with virtually no clipping at all.

D. A Note On Terminology

33. There is some overlap and apparent inconsistency with certain terminology in the art. Particularly confusing is the use of "symbol." Generally, "symbol" can have two meanings. First, "symbol" can refer to information transmitted on one carrier. Second, "symbol" can refer to all of the information transmitted in a "symbol period." In the case of a multicarrier symbol, there are multiple carrier "symbols" but only one collective "symbol." The individual carrier symbols are often referred to as "QAM symbols," where "QAM" (Quatrature Amplitude Modulation) is a commonly-used type of modulation used to modulate a carrier symbol onto a carrier. A multicarrier "symbol" (*i.e.*, the collection of multiple carrier symbols) in a DMT system is often referred to as a "DMT symbol," where "DMT" (Discrete Multitone) is a type of multicarrier technology.

34. In order to keep things clear and to avoid apparent inconsistency/overlap with the term "symbol," this declaration employs the terms "carrier" and "symbol" as follows:

- "carrier" means a carrier symbol (*e.g.*, a QAM symbol); and

- "symbol" means a collective multicarrier symbol in a single symbol period (*e.g.*, a DMT symbol).

35. This declaration also uses appropriate editorializing to distinguish between a "carrier" and a "symbol" in the references of record and Petitioners' expert's declaration.

36. Further adding to potential confusion is that the terms "carrier," "subcarrier," "band," "sub-band," "bin," "channel," and "tone" are often used interchangeably. Ex. 1011 at 1:42–43 ("sub-bands or frequency bins"); *id*. at 1:48 ("sub-band channels"); *id*. at 5:13–15 ("carrier"); *id*. at 10:40–41 ("subcarriers"); *id*. at 12:39 ("bin (channel)"); Ex. 1012 at 1:41 ("tones or bands"). For consistency, "carrier" is used as much as possible in this declaration.

VI. CLAIM CONSTRUCTION–"SCRAMBLING…A PLURALITY OF CARRIER PHASES"

37. In the context of the '243 patent, "scrambl[e/ing]…a plurality of carrier phases"—or the variant "scramble…a plurality of phases"—should be construed to mean "adjusting the phases of a plurality of carriers in a single multicarrier symbol by pseudo-randomly varying amounts." This construction is fully supported by the specification of the '243 patent, and it clarifies that phase scrambling is performed amongst individual carrier phases in a single multicarrier

symbol. In other words, phase scrambling is not met if the phase adjustment only occurs over time from one symbol to the next.

38. The '243 patent is directed exclusively to multicarrier modulation systems. *See* Ex. 1001 at 1:26–29 ("This invention relates to communications systems using multicarrier modulation. More particularly, the invention relates to multicarrier communications systems that lower the peak-to-average power ratio (PAR) of transmitted signals."); 3:32–37 ("Although described with respect to discrete multitone modulation, the principles of the invention apply also to other types of multicarrier modulation, such as, but not limited to, orthogonally multiplexed quadrature amplitude modulation (OQAM), discrete wavelet multitone (DWMT) modulation, and orthogonal frequency division multiplexing (OFDM)."). Furthermore, every independent claim is directed to a "multicarrier communications transceiver" (claims 1, 7, and 20) or a "multicarrier transmitter" (claim 13). The '243 patent discloses several multicarrier techniques and uses "discrete multitone modulation" ("DMT") as an example. *Id*. at 3:32–37.

39. A multicarrier signal includes the combination of a plurality of carriers, where each carrier is transmitted at a different frequency and has its own phase. In the embodiment of the '243 patent, each of the plurality of carriers corresponds to a different QAM symbol. *See, e.g., id.* at 4:13–14 ("The modulator 46 modulates each carrier signal with a different QAM symbol 58."). Each carrier

(or QAM symbol) has its own phase or phase characteristic. *See*, *e.g.*, *id.* at 4:7–9 ("The QAM symbols 58 represent the amplitude and the phase characteristic of each carrier signal."). The combination of these carriers (or QAM symbols) is referred to as a DMT symbol (which is an exemplary type of multicarrier symbol). *See, e.g.*, *id.* at 9:8–9 ("…a set of QAM symbols 58 produces a DMT symbol 70….").

40. The term "phase characteristic" in the '243 patent is interchangeable with "phase." *See*, *id.*, at 1:40–42 ("The DMT transmitter typically modulates the phase characteristic, or phase, and amplitude of the carrier signals….").

41. The '243 patent repeatedly discloses a "phase scrambler" that scrambles the phases or phase characteristics of carriers within a single DMT symbol. *See*, *id.*, at 6:52–8:13.

42. There is no disclosure in the '243 patent of scrambling carrier phases amongst different symbols. As the '243 patent explains, it is the adjustment of a plurality of carrier phases within a single DMT symbol that reduces the PAR of the transmission signal. Ex. 1001 at 4:35–38 and 6:48–53. If the carrier phases were only adjusted from one DMT symbol to the next, PAR would not be reduced.

VII. OVERVIEW OF ASSERTED REFERENCES—SHIVELY AND STOPLER

A. Shively

43. Shively discloses a concept that is intended to increase the useable bandwidth in a multicarrier communications system. Ex. 1011 at 1:5–20. Shively teaches a theoretical way to transmit data over a transmission medium having high signal attenuation at frequencies corresponding to a significant number of carriers.

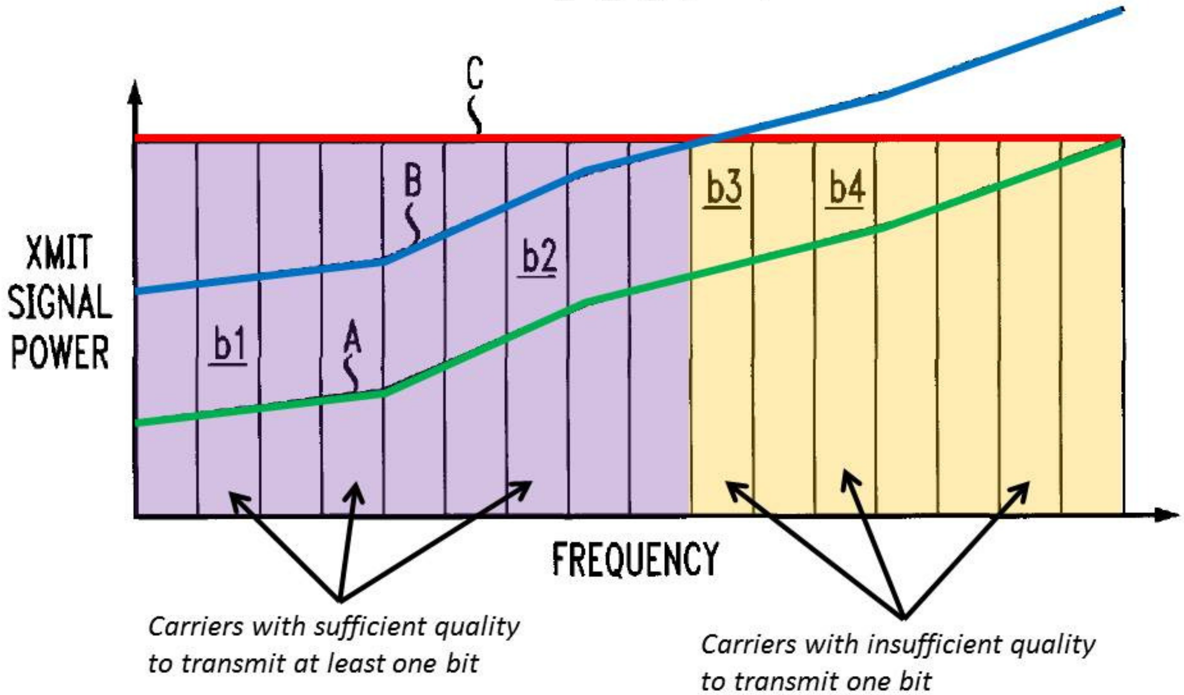
44. To appreciate Shively's teachings, it necessary to understand such impaired transmission mediums. Shively specifically describes "long loop" systems, where the length of cable between transmitting and receiving DSL modems is ***at least*** 18,000 feet (about 3.4 miles):

> Referring to FIGS. 1 and 2, a transmitting modem 31 is connected to a receiving modem 32 by a cable 33 having four twisted pairs of conductors. In long loop systems where cable 3 is of length of the order ***18,000 feet or more***, high signal attenuation at higher frequencies (greater than 500 kHz) is usually observed. This characteristic of cable 33 is represented graphically by curve A in FIG. 1.

Id. at 9:63–10:2 (emphasis added). *See also id.* at 11:11–12 ("Such noisy and/or highly attenuated sub-bands can occur for example in long-run twisted pair conductors.").

45. FIG. 1 of Shively, which is annotated with color below, is illustrative:

FIG. 1



46. FIG. 1 of Shively shows carriers at increasing frequencies along the x-axis. Each carrier is delineated by vertical lines. Power level is indicated along the y-axis. Green line (A) represents an attenuation/noise floor, which increases as a function of frequency. *Id.* at 2:1–12. Shively explains that attenuation at higher frequencies is a problem across long cables. *Id.* at 9:65–10:2 ("In long loop systems where cable 3 is of length of the order 18,000 feet or more, high signal attenuation at higher frequencies (greater than 500 kHz) is usually observed."). Green line (A) is a characteristic of a communications channel, and it does not illustrate a transmitted signal. *Id.* at 10:61–11:12.

47. Blue line (B) is the minimum power margin above the attenuation/noise floor (green line (A)) that is required to transmit a single bit. *Id.* at 2:8–10. Red line (C) illustrates a "spectral density mask," which is a type of power limit imposed by system design. *Id.* at 2:10–12 ("Curve C represents the limits imposed by a power spectral density mask imposed by an external communications standard."). Power transmitted in a given carrier cannot exceed red line (C).

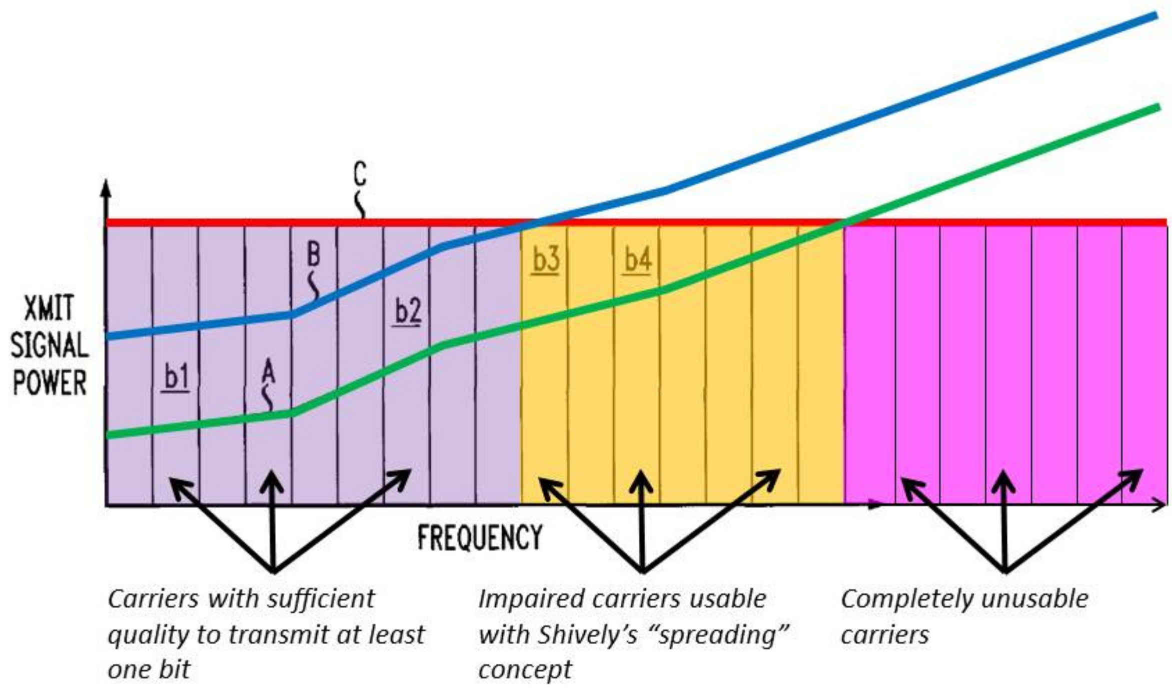
48. As FIG. 1 illustrates, blue line (B) is below red line (C) for the carriers shaded in purple. In these purple-shaded carriers, there is sufficient headroom to transmit a signal representing at least one bit without exceeding a power limit. For the carriers shaded in orange, however, blue line (B) exceeds red line (C). Because the noise and attenuation for these orange-shaded carriers is too high (A), a bit cannot be reliably transmitted without exceeding the imposed spectral density mask. In other words, the minimum required power margin (B) is greater than the spectral density mask (C). *Id.* at 10:65–11:3.

49. Shively proposes a way to transmit data on some of the orange-shaded carriers. Specifically, replicated data is sent across multiple orange-shaded (impaired) carriers using power or energy levels at or below the spectral density mask—*i.e.*, red line (C). Because red line (C) is lower than blue line (B), the power level on a given orange-shaded carrier is too low to reliably transmit a bit.

Shively makes use of this available power by "spreading" a single bit of data across multiple impaired carriers.

50. Shively's concept combines (adds) these otherwise too-low-power signals (that were sent on the impaired carriers) at the receiver to recover the information. "According to the invention, digital modulator 14 replicates ('spreads') a k-bit symbol over multiple adjacent bands with correspondingly less energy in each band. At the receiving end, detector 49 coherently recombines ('despreads') the redundant symbols in the noisy/attenuated sub-bands. In recombining the symbols, the symbols are simply arithmetically added. Because the noise is incoherent while the signal is coherent, the noise tends to be averaged out while the signal is reinforced by the addition process." *Id.* at 11:16–24.

51. Although not explicitly depicted in FIG. 1, one having ordinary skill in the art understood that there are carriers in addition to those shaded in purple and orange that are completely unusable under any circumstance—even with Shively's concept. According to this reality, FIG. 1 can be expanded to look like this:



52. The pink-shaded carriers are at frequencies higher than the orange-shaded carriers. The pink-shaded carriers are completely unusable because the noise/attenuation floor (green line (A)) is greater than the imposed spectral density mask power limit (red line (C)).

53. Shively discloses two different modes of operation for ADSL-1995: (1) a normal mode and (2) a "power-boost" mode. The normal mode is referenced by Shively's statement that: "The other limit is on the aggregate power, also defined by an external communication standard, e.g., ANSI Standard T1.413-1995 [(ADSL-1995)] limits the total power for all sub-bands to 100 mWatts." Ex. 1011 at 2:12–15. When referring to the cited standard, one having ordinary skill in the

art would have understood that this aggregate power limit corresponds to the normal mode. The normal mode has an aggregate power limit of 20.4 dBm, which is about 109.6 mW (approximately 100 mW). Ex. 1017 at p. 65. § 6.13.3 ("The normal aggregate power level shall not exceed…20.4 dBm if all sub-carriers are used[].").

54. The power-boost mode of ADSL-1995 is also described by Shively:

> The power spectral density mask may be dictated by the standard used in a particular country implementing the standard (such as A.N.S.I. standard T1.413-1995 [(ADSL-1995)])…For example, the power limit for frequencies or tones between 0 and 200 kilohertz must be less than -40 dBm/Hz (a power level referenced to one milliwatt over 1 Hz bandwidth). Above 200 kHz (to frequencies in the megahertz of spectrum), the constraint may be -34 dBm/Hz.

Ex. 1011 at 1:51–65. When referring to ADSL-1995, one having ordinary skill in the art would have understood that this spectral density mask scheme—lower power (-40 dBm/Hz) at lower frequencies and higher power (-34 dBm/Hz) at higher frequencies—describes the ADSL-1995 power-boost mode.

55. The power-boost mode is illustrated below in a figure excerpted from the ADSL-1995 standard, Ex. 1017 at p. 66:

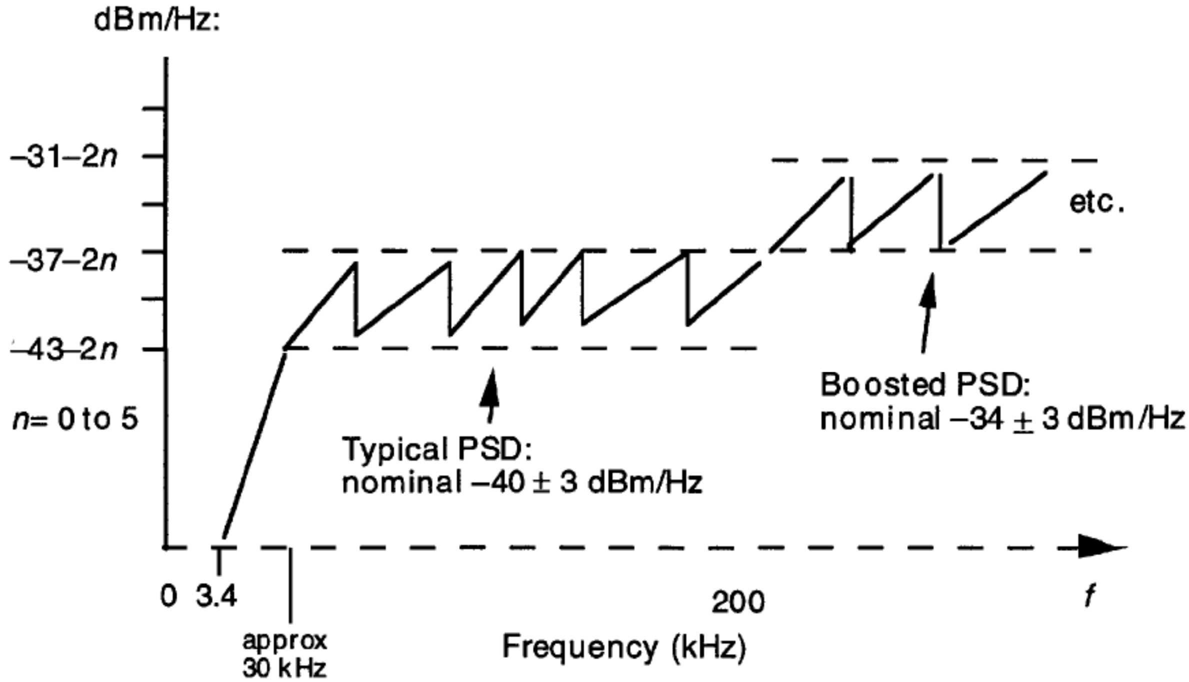


Figure 18 – ATU-C transmitter PSD mask: pass-band detail

Note, in the figure above, "PSD" stands for power spectral density, which corresponds to the spectral density mask power limit. *See* Ex. 1017 at p. 61, § 6.8.

56. While the normal mode has an aggregate power limit of approximately 110 mW, the aggregate limit of the power-boost mode is approximately 344 mW. *See* Ex. 1017 at p. 66 ("a power boost…total power = the sum of the powers (-4 + 10log(*ncdown1*)) and (2 + 10log(*ncdown2*)), where *ncdown1* and *ncdown2* are the number of subcarriers used in the sub-bands *i* = 0 to 50, and *i* = 51 to 255, respectively."). Petitioners' expert, however, misunderstood Shively by imagining that a 100 mW aggregate power limit would be used in the power-boost mode. In particular, during cross-examination regarding the bases for

his opinions regarding Shively, Dr. Tellado testified that he interpreted Shively as disclosing a single mode in which the spectral density mask is -40 dBm/Hz for carriers in the frequency band up to 200 kHz and -34 dBm/Hz for carriers in the frequency band above 200 kHz and an aggregate power limit of approximately 100 mW. Ex 2002 at 43:7–25. But this is wrong because it is inconsistent with the ADSL-1995 standard to which Shively's disclosure is directed.

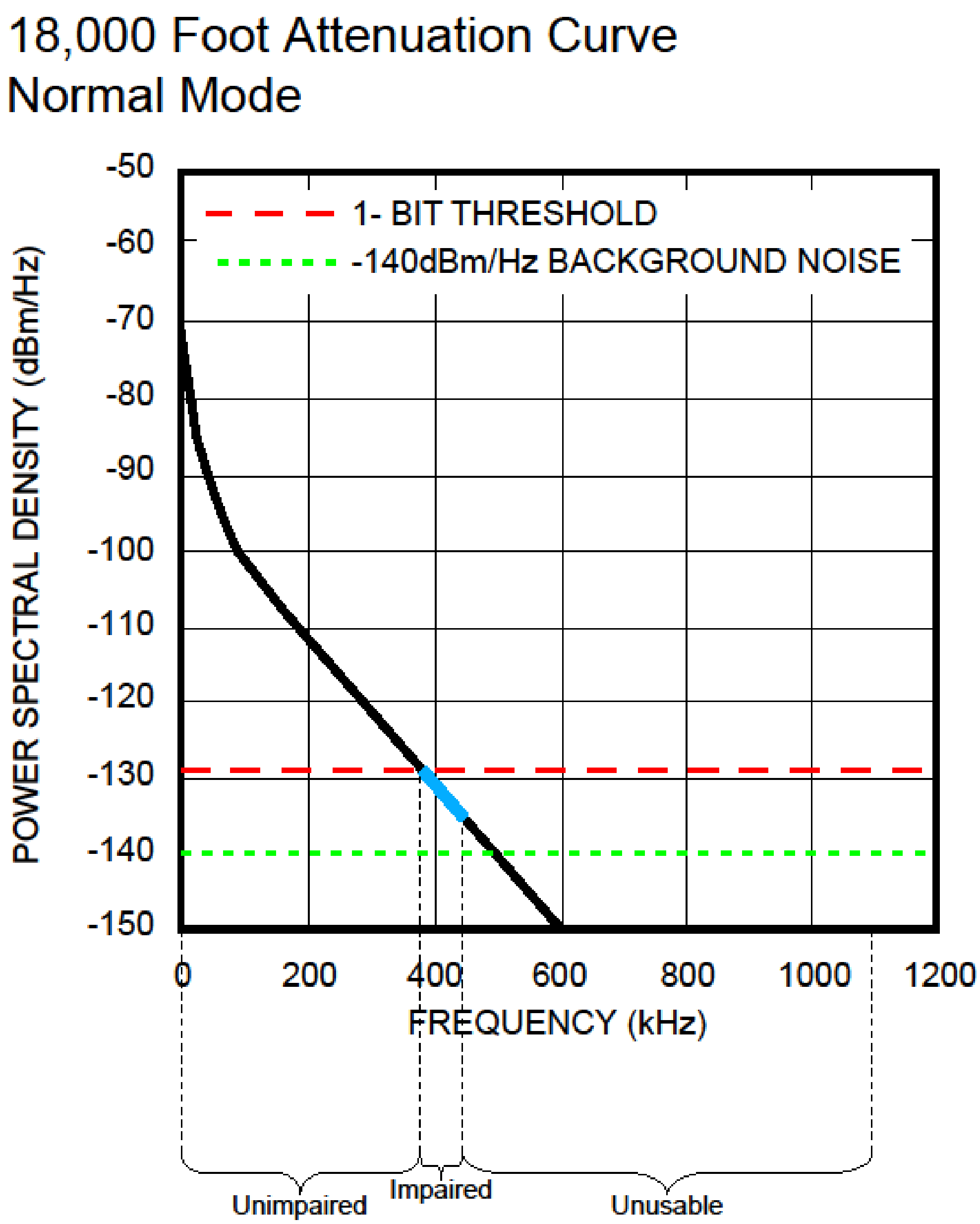
57. In fact, having such a low aggregate power limit (less than 1/3 of the actual limit) would defeat the purpose of having a power-***boost*** mode. One having ordinary skill in the art would have readily paired the correct aggregate power limit and spectral density mask for a particular mode when consulting the ADSL-1995 standard to which Shively's disclosure is directed. To the extent Shively is incorrectly interpreted as disclosing a single mode in which the spectral density mask is -40 dBm/Hz for carriers having frequencies up to 200 kHz and -34 dBm/Hz for frequencies above 200 kHz (as is the case for boosted mode of ADSL-1995) and a total power limit of approximately 100 mW (as is the case for the normal mode of ADSL-1995), one of skill in the art would recognize this as an obvious error.

58. In Shively's proposed system using normal mode for ADSL-1995 across 18,000 foot cables, about 34% of the carriers are unimpaired, about 6% of the carriers are impaired, and about 60% of the carriers are unusable. Thus, ***more***

than half of the carriers cannot be used at all. Consequently, the power of a transmitted signal will be reduced by 60%, thereby resulting in power levels only 40% of maximum.

59. The Figure below (extracted and modified from Exhibit 2009) shows a different view of the concept illustrated in Shively's FIG 1, with additional technical detail added. This curve shows the power level at the receiver in an ADSL system using an 18,000 foot loop as described in Shively. The noise level in the receiver is constant (a known fact from the physics of materials) and is approximately -140dBm/Hz and shown by the dashed green line. This is consistent with Shively, FIG 1. As known to a person of ordinary skill in the art, in order to demodulate a single bit with a probability of error of 10^{-7}, the signal power must be at least 11.3dB above the noise floor (*i.e.*, at least -128.7 dB). This level is shown by the dashed red line. Thus only the frequencies with power levels above the dashed red line are capable of carrying a single bit or more. On the other hand, as the signal power approaches the noise floor, the carriers become completely unusable since there is not enough power to coherently combine with the other carriers, nor is there sufficient signal to make adequate phase estimates to make the coherent combining possible. Shively's technique only applies to frequencies in between the unimpaired carriers (*i.e.*, those to the left of the intersection with the black/blue line and the dashed red line) and the unusable

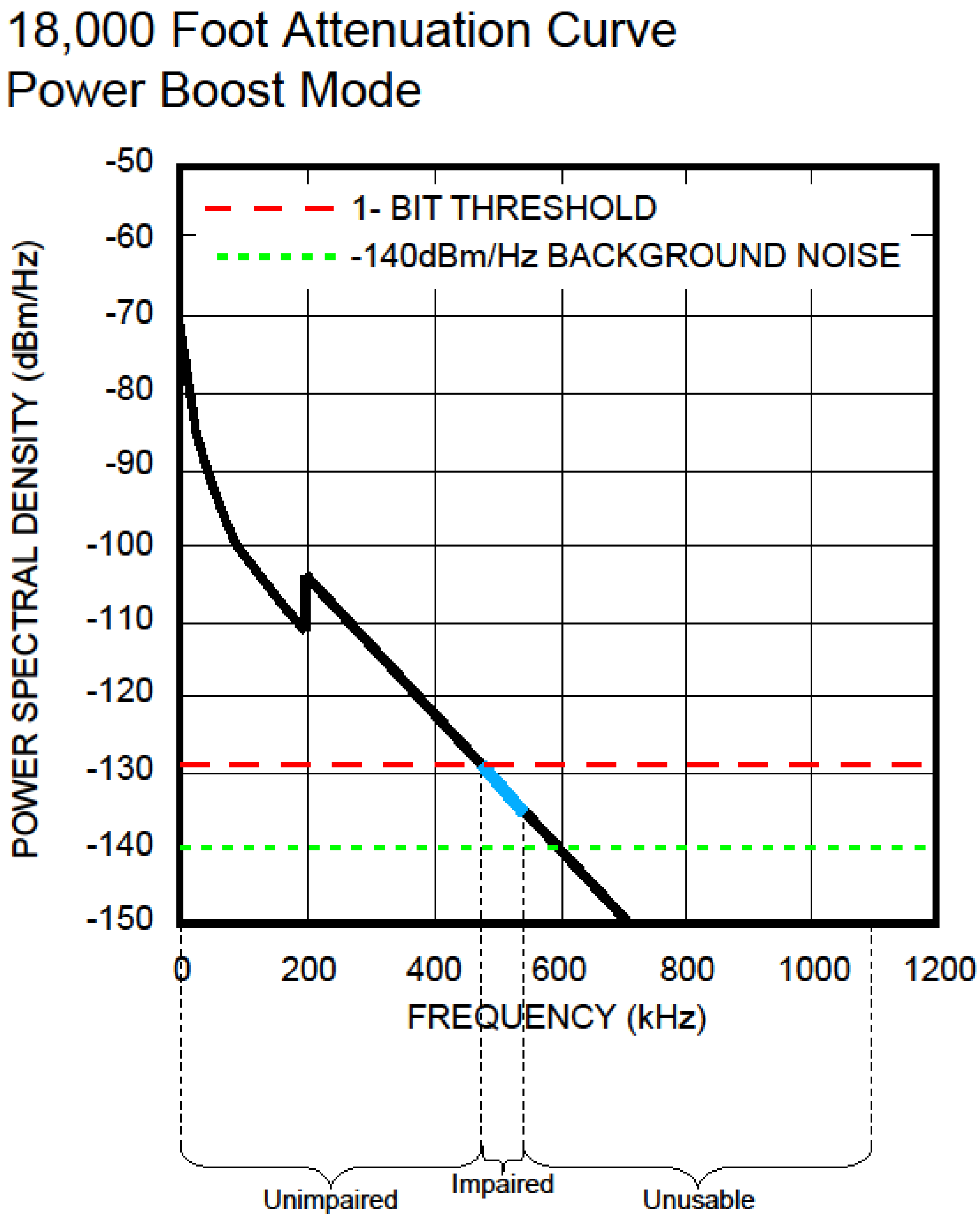
carriers (*i.e.*, those below the noise floor where the black line crosses the dashed green line). Thus, only the carriers in the blue shaded region are usable for Shively's method. By comparing the unusable frequencies with the usable frequencies, even with Shively, less than 40% of the carriers are usable, and the total power will be reduced proportionately.



60. In Shively's proposed system using power-boost mode for ADSL-1995 across 18,000 foot cables, about 43% of the carriers are unimpaired, about 6% of the carriers are impaired, and about 51% of the carriers are unusable. Again, more than half of the carriers cannot be used at all. Consequently, the

power of a transmitted signal will be reduced by 51%, thereby resulting in power levels only 49% of maximum.

61. The Figure below (extracted and modified from Exhibit 2009) shows a different view of the concept illustrated in Shively's FIG 1, with additional technical detail added. In this case the additional power in power boost mode is shown in the Figure. This curve shows the power level at the receiver in an ADSL system using an 18,000 foot loop using power-boost mode as described in Shively. As before, the noise floor is the dashed green line and the single bit threshold is the dashed red line. And, as before, only the carriers in the blue shaded region are usable for Shively's method. As before we see that somewhat less than ½ the carriers are usable, even with Shively, and the total power will be reduced accordingly.



62. While Shively's "spreading" idea will cause a small uptick in clipping probability, any increase is negated many times over by the enormous reduction in clipping achieved by reducing signal power by more than half. Based on worst-

case assumptions regarding Shively's spreading idea, the clipping probability for both normal and power-boost modes is virtually zero.

63. While Shively's "spreading" idea will cause a small uptick in clipping probability, any increase is negated many times over by the enormous reduction in clipping achieved by reducing signal power by more than half. Based on worst-case assumptions regarding Shively's spreading idea, the clipping probability for both normal and power-boost modes is virtually zero.

64. Using techniques that are well known to persons of ordinary skill in the art, in a system with 256 carriers as described in Shively, the clipping probabilities may be computed as follows. The normal mode has an aggregate power limit of 20.4 dBm, which is about 109.6 mW (approximately 100 mW). Ex. 1017 at p. 65. § 6.13.3 ("The normal aggregate power level shall not exceed…20.4 dBm if all sub-carriers are used[]."). The aggregate limit of the power-boost mode is approximately 344 mW. *See* Ex. 1017 at p. 66 ("a power boost…total power = the sum of the powers (-4 + 10log(*ncdown1*)) and (2 + 10log(*ncdown2*)), where *ncdown1* and *ncdown2* are the number of subcarriers used in the sub-bands *i* = 0 to 50, and *i* = 51 to 255, respectively."). It is well known that a multicarrier signal may be approximated by a Gaussian random variable with zero mean and variance P_s. Thus the probability of clipping is $P\{|s(t)|<T\}<10^{-7}$, where T is the clipping threshold of the transmitter system and s(t) is the multicarrier signal. Using

standard, well-known, statistical techniques we find that T=5.3*sqrt(P_s). Since the modem must be designed to accommodate all conditions, including both short and long loops the clipping threshold must be set to at least 5.3*sqrt(P_s).

65. Now consider the case for a long loop. From the Figure above, there is approximately 380kHz of unimpaired bandwidth, which is equivalent to 88 carriers. Since each carrier is limited to the same value of P_c as in the long loop, the resulting transmitted signal has power P_s'=88 * 0.43125 = 37.95mW and may be reasonably modeled as a Gaussian random variable with a variance of P_s'. The probability of clipping in this case is P{|s'(t)|<T}=1.4*10^{-19}. This probability is far below the required probability of 10^{-7} and so there is no PAR problem with this this system. In other words the clipping rate is miniscule.

66. If we add Shively carriers in groups of 4 as Shively teaches, we find that, with a maximum of 16 (4 groups of 4) Shively carriers, the total average power in the resulting signal is P_{sh} = 37.95mW + 16*0.43125 = 44.85mW, and may be approximated by a Gaussian random variable with variance P_{sh}. In this case, the probability of clipping is 8.3*10^{-17}. Assuming a sampling rate of 2.2 MHz for ADSL-1995, this would result in a clipping error once every 173.7 years, on average. Thus Shively does not contribute significantly to clipping and PAR is not a problem using the Shively technique. Note that it could be argued that adding 4 groups of 4 subcarriers will not result in a Gaussian signal, but in fact the

Gaussian approximation is still quite reasonable since there are a small number of Shively carriers compared to the total. .

67. In the case of power boost mode, the computations are nearly identical, except that the total power is increased. In the power boost mode, there are 111 usable subcarriers (480kHz/4.3125kHz). The first 51 carriers transmit 0.43125mW and the next 60 carriers transmit 4 times (6dB) more for a total power of 125.5mW. If we assume that the system was designed for 256 (51 non-boosted and 205 boosted) carriers so the total power is 344mW and the clipping threshold is T=5.3*sqrt(344). The total power in the 111 usable carriers is 125.5mW and the probability of clipping is $1.1*10^{-18}$. Adding the Shively carriers as before we find a clipping probability of $1.4*10^{-15}$. Assuming a sampling rate of 2.2 MHz, this would result in a clipping error once every 10.3 years, on average. So once again the system described in Shively has no PAR problem.

68. For cable lengths longer than 18,000 feet, an increasing number of carriers becomes unusable (pink-shaded), resulting in even greater reductions in clipping probabilities. Not surprisingly, Shively does not mention anything about clipping or PAR.

B. Stopler

69. Unlike Shively, Stopler proposes an idea for use with both multicarrier systems and "single-carrier" systems. Unlike multicarrier systems

(which transmit a signal with multiple phases), a single-carrier system transmits a signal using only one carrier, which has only one phase.

70. Stopler specifically teaches that his concept can be used with single-carrier code-division multiple access ("CDMA") systems. *See, e.g.,* Ex. 1012 at 12:58–63 ("The framing scheme according to the present invention may also be performed in a CDMA system, in which case the modulator (not shown) may, for example, be a CDMA-type modulator in accordance with the TIA/EIA/IS-95 'Mobile Station Compatibility Standard for Dual Mode Wideband Spread Spectrum Cellular System.'").

71. As Petitioners' expert explained during cross-examination, some CDMA techniques can be used in a multicarrier system. Ex. 2002 at 110:20–25. However, Stopler only refers to CDMA techniques that are disclosed in two references: (1) TIA/EIA/IS-95; and (2) "Proakis, 'Digital Communications,' Chapter 15.". Ex. 1012 at 3:37–47 and 12:58–63. Both TIA/EIA/IS-95 and Proakis are incorporated by reference into Stopler. *Id.* at 3:37–47. Both describe single-carrier CDMA techniques, exclusively. *See* Ex. 2005; Ex. 2006.

72. FIG. 5, which shows Stopler's "framing scheme" (Ex. 1012. at 8:54–55), is illustrative:

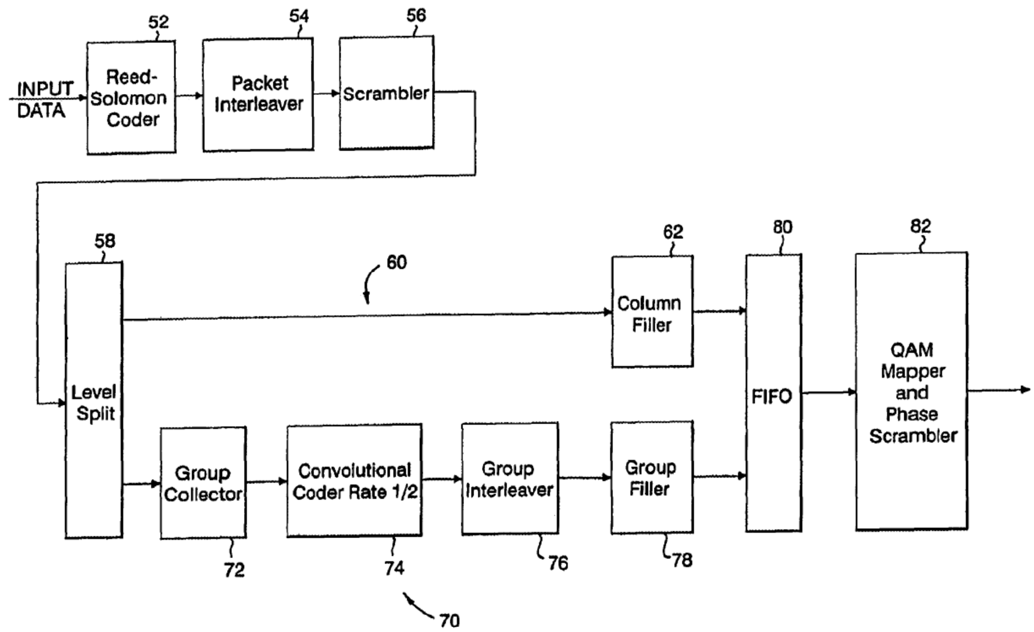


FIG. 5

73. Significantly, there is a block missing from FIG. 5—namely, a block downstream from the QAM Mapper/Phase Scrambler 82.

74. The missing block would specify the type of "modulation" to be used, whether the modulation be single-carrier or multicarrier. *See id.* at 12:55–57 ("The output from the QAM mapper 82 is provided to ***a modulator (not shown)*** which implements the particular signal modulation desired, e.g., VCMT, CDMA, etc.")(emphasis added).

75. VCMT stands for "variable constellation multitone." *See id.* at 2:9. This is a type of multicarrier technique.

76. The missing block downstream from the QAM Mapper/Phase Scrambler 82 could be a multicarrier modulator or a single-carrier modulator. In

either case, Stopler's phase scrambling scheme must at least be compatible with single-carrier CDMA. This fact is reflected in Stopler's claims. For example, claim 25 of Stopler recites a "method of arranging and transmitting data in a CDMA system." Ex. 1012 at 16:4–5 (emphasis added). And claim 31, which depends from claim 25, recites "phase scrambling": "31. The method of claim 25, wherein prior to said utilizing step, said method includes the step of phase scrambling said upper level data and said second encoded data in accordance with said second encoded data." *Id*. at 16:45–48 (emphasis added). So, plainly, Stopler's phase scrambling idea must be compatible with single-carrier CDMA.

77. Petitioners' expert asserted (during cross-examination) that Stopler's phase scrambling is not performed over time from symbol-to-symbol. Ex. 2002 at 107:15–18 ("Q. So you're suggesting that each symbol from one symbol to the next would have a different phase rotation? A. No. No. Individual QAM symbols within the same modulation block."). This is wrong.

78. Single-carrier CDMA must be operable with Stopler's phase scrambling. Single-carrier systems have only one carrier with only one phase. It is nonsensical to scramble phases within a symbol because there is only one phase in each symbol. Phase scrambling in a single-carrier system only makes sense when it is performed over time from symbol-to-symbol.

79. There are various reasons that would have been recognizable to one having ordinary skill in the art for performing phase scrambling from symbol-to-symbol. For example, Petitioners' expert suggested that pilot tones could be scrambled over time "not to create a DC bias." Ex. 2002 at 95:7–9.

80. Another example for phase scrambling from symbol-to-symbol is detailed in U.S. Pat. No. 6,370,156 ("the '156 patent"), which has a priority date of January 31, 1997 (which is before the November 9, 1999 priority date of the '243 patent). The '156 patent identifies a problem of "narrowbanded" interference in ADSL-1995. Ex. 2004 at 1:55–2:16. This identical problem is also discussed in Stopler, as depicted in FIG. 4:

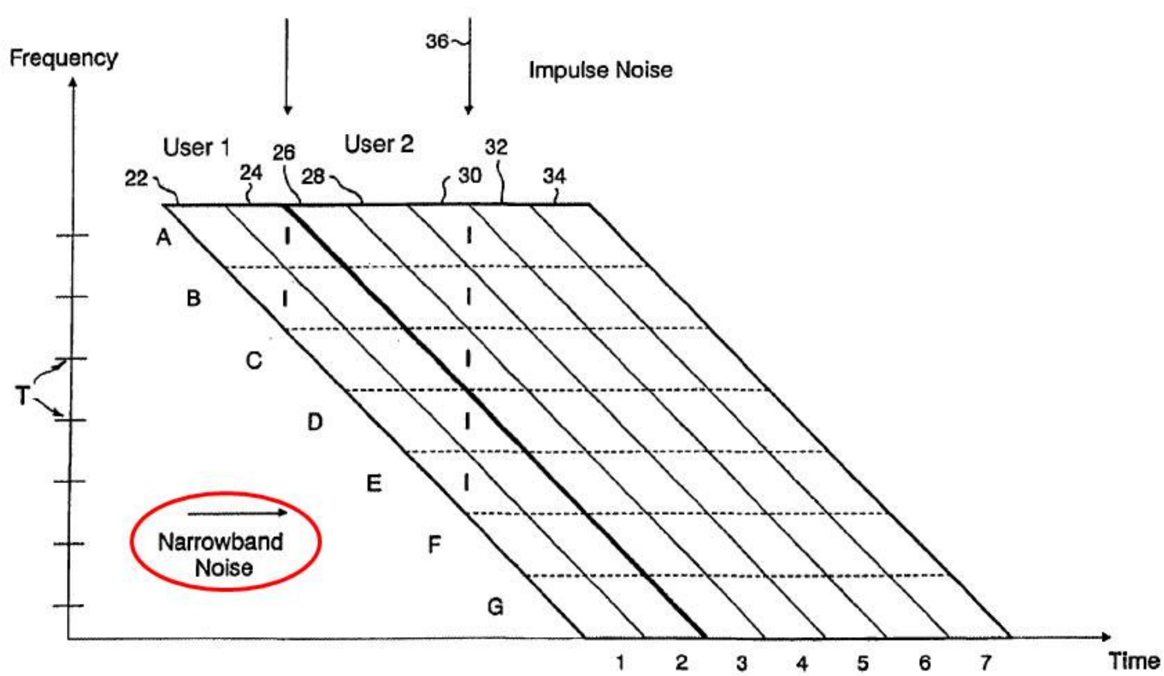


FIG. 4

81. Stopler further explains: "One type of noise is ingress or narrowband interference which typically occurs at a fixed frequency and lasts for a long time." Ex. 1012 at 1:36–38. Stopler claims that his "invention" "allows efficient operation in multipoint to point channels which are affected by ingress (narrowband noise) and impulsive (burst) interference." *Id.* at 5:10–14. But Stopler does not explicitly explain how he addresses the problem of narrowband noise, despite that narrowband noise is flagged as an issue.

82. Stopler addresses narrowband noise in two ways. First, as shown in Figure 4, a given carrier (*e.g.*, carrier E) is assigned to a first user (*e.g.*, User 1) at some times and to a different user (*e.g.*, User 2) at other times. If narrowband noise corrupts carrier E, the resulting bit errors have reduced impact on each user compared to a system in which a given carrier is always assigned to a single user. This solution works for data, but it will not work for an overhead pilot carrier because such a pilot must be received by all users at all times to allow the receiver of each user to remain synchronized with the system. Thus, narrowband noise at the frequency of pilot tones must be addressed differently. Stopler addresses narrowband noise at the frequency of an overhead pilot carrier by scrambling the phase of the pilot carrier over time from one DMT symbol to the next, *i.e.*, by inter-symbol phase scrambling.

83. The teachings of the ’156 patent reveal how Stopler’s inter-symbol phase scrambling concept reduces the problem of narrowband noise that interferes with a pilot carrier. The ’156 patent explains that ADSL-1995 has one carrier that is assigned to be a pilot. Ex. ___ at 1:61–63 (“As is indicated in [the ADSL-1995 standard], one of the carriers is reserved as a pilot carrier.”). Then, the technique of phase scrambling the pilot carrier from symbol-to-symbol is explained: “In a particular implementation of the present invention, the pilot carrier is modulated as a random or pseudo-random signal. In this way, by modulating a randomised signal on the pilot carrier, the state of the pilot carrier in the constellation scheme will change randomly so that the demodulation will have a good averaging effect resulting in an increase of the interference immunity.” *Id.* at 4:39–47. “It is to be remarked that, to have significant immunity against interferers, the data elements which are modulated on the pilot carrier, [have] to be sufficiently random so that the pilot carrier reaches all states in the constellation scheme and a good averaging of the interference is obtained by demodulation. This can be obtained by scrambling.” *Id.* at 5:11–17 (emphasis added).

84. Petitioners’ expert’s argument that Stopler discloses phase scrambling within one symbol is based on the premise that the symbol can have multiple pilot tones. Yet Petitioners’ expert’s declaration do not discuss or allude to even one system or standard that uses multiple pilot tones in a single symbol. Instead,

Petitioners' expert identifies only ADSL(Ex. 1009 at ¶ 58). But ADSL has exactly one pilot tone in a symbol, not multiple pilot tones. Ex. 1017 at p. 62, § 6.9.1.2.

85. Petitioners' expert highlights the ADSL standard and admits that it is implemented in Stopler. CITE ("Stopler also explains that its signal transmission scheme may implement techniques of DSL standards such as 'ADSL (Asymmetric Digital Subscriber Line).'"). Starting with the next sentence, Petitioners' expert further states: "Stopler also explains that some of the available carriers may be reserved for the transmission of overhead signals, such as pilot tones. Ex. 1012, 10:60-62 & 12:51-54. To randomize these overhead channels, Stopler employs a phase scrambler. Ex. 1012, 12:24-26. A POSITA would have understood that the values transmitted in an overhead channel may not be random, and in fact, may be highly structured. Ex. 1009, p. 24. Without the phase scrambler, the structured nature of the overhead channel could contribute to an increase in the peak-to-average power ratio of the transmitter. Ex. 1009, pp. 24-25." Ex. 1009 at ¶ 59. Petitioners' expert, upon cross-examination, clarified that "highly structured" means that multiple pilot tones are present in single symbol. Ex. 2002 at 105:11–20 ("Q. …What do you mean by 'highly structured'? A. For example, if the pilot tone is the same value in all overhead channels, that's an example of structured; repeating the same value multiple times."); and 109:1–5 ("A.…[Stopler] specifically says 'overhead symbols,' which could be interpreted to having two or

more overhead symbols in one block. And that was my interpretation. It still is my interpretation.”). But Petitioners’ expert did not realize that ADSL has only one pilot tone. Ex. 2002 at 90:11–14 (“Q. Okay. So in an ADSL system, according to the T1.413 standard, for example, there's a single pilot tone; correct? A. I don't know that.”). Petitioners’ expert’s declaration is based on incomplete information about ADSL.

86. Instead of understanding that ADSL has only one pilot tone, Petitioners’ expert based his opinion on the fact that Stopler refers to “overhead carriers” and that these multiple symbols must be in one symbol. Ex. 2002 at 109:1–5. Petitioners’ expert specifically testified: “[Stopler] specifically says ‘overhead symbols,’ which could be interpreted to having two or more overhead symbols in one block. And that was my interpretation. It still is my interpretation.” Ex. 2002 at 109:1–5. To clarify a matter of terminology, (1) “overhead symbols” corresponds to “carriers,” and (2) “block” corresponds to “symbol” as used in this declaration. But the correct interpretation of Stopler’s reference to plural “overhead carriers” is that (a) there is one overhead carrier per symbol and (b) there are multiple symbols. *Ergo*, Stopler refers to multiple overhead carriers.

87. As demonstrated by the ’156 patent, it was known by those with skill in the art to scramble the phases on a pilot carrier from one single-carrier symbol to

the next in order to reduce the problem of narrowband noise. Petitioners' expert's uninformed view, by contrast, is that Stopler's phase scrambling would be performed within one multicarrier symbol to reduce PAR. Ex. 1009 at ¶ 60. Stopler, however, is silent on issues related to PAR, and, in fact, does not mention the word "power" or PAR, or teach that its disclosure could be used to resolve PAR problems, as confirmed by Petitioners' expert:

> Q. Okay. And Stopler does not mention peak-to-average power ratio, does it?
>
> A. I did not see it.
>
> Q. Okay. And it doesn't state anywhere that it's addressing a PAR issue; correct?
>
> A. I didn't see that.
>
> Q. And it doesn't say anywhere that its teachings could potentially reduce PAR; correct?
>
> A. I didn't see it.
>
> Q. Okay. Would you be surprised if I told you that the Stopler reference doesn't even mention the word "power"?
>
> A. I didn't see it. I'm not surprised.

Ex. 2002 at 97:6–18.

88. There is no reason that Stopler would discuss PAR because his technique of scrambling phases from one symbol to the next does not reduce PAR.

89. Instead of Petitioners' theory about reducing PAR, Stopler sheds some light as to why he suggests performing "phase scrambling." Stopler's only stated reason for scrambling phases is "to randomize the overhead channel symbols" plural. Ex. 1012 at 12:24–26. Because Stopler must be compatible with single-carrier CDMA, the only reasonable conclusion is that Stopler's reference to "overhead channel symbols" plural refers to scrambling phases from symbol-to-symbol.

90. Furthermore, Stopler states that the phase scrambler is "applied to all symbols, not just the overhead symbols" in order "to simplify implementation." But performing phase scrambling according to Petitioners' interpretation—*i.e.*, each carrier is scrambled within a symbol such that the carriers have a random distribution of phases—would add complexity to Stopler's system. The sensible interpretation of Stopler's statement is that all of the carriers within a symbol are rotated by the same phase shift with the phase shift changing from symbol to symbol, but NOT carrier to carrier. Instead, the only simplifying way to execute Stopler's directive is to rotate the phases of each carrier by the same amount.

US006370156B2

(12) **United States Patent**
Spruyt et al.

(10) **Patent No.: US 6,370,156 B2**
(45) **Date of Patent: *Apr. 9, 2002**

(54) **MODULATION/DEMODULATION OF A PILOT CARRIER, MEANS AND METHOD TO PERFORM THE MODULATION/ DEMODULATION**

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(73) Assignee: **Alcatel**, Paris (FR)

(*) Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **08/844,383**

(22) Filed: **Apr. 18, 1997**

(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**[7] **H04B 3/10**; H04J 3/06; H04L 7/00

(52) **U.S. Cl.** **370/480**; 370/206; 370/491; 370/515; 375/222; 375/357; 375/367

(58) **Field of Search** 370/203, 204, 370/206, 207, 208, 480, 484, 491, 515, 468, 210, 332, 474; 375/222, 357, 367, 377, 200, 285, 131; 455/10

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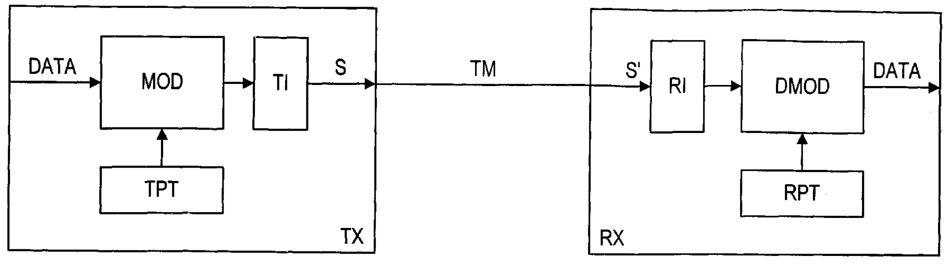
Primary Examiner—Hassan Kizou
Assistant Examiner—John Pezzlo
(74) *Attorney, Agent, or Firm*—Ware, Fressola, Van Der Sluys & Adolphson LLP

(57) **ABSTRACT**

For synchronisation purposes, a transmitter (TX) multiplexes a pilot carrier with carriers whereon data elements (DATA) are modulated, and transmits the pilot carrier together with the modulated carriers to a receiver (RX). The immunity of the pilot carrier from interference, such as radio amateur signals, is improved by modulating the pilot carrier with a non-constant signal, for instance a random signal, an alternating signal or even scrambled data elements (DATA), before transmission thereof. Since demodulation of the pilot carrier in the receiver (RX) and averaging successive demodulated pilot carriers reduces the effect of the interference induced on the non-constantly modulated pilot carrier, the degradation of the synchronisation between transmitter (TX) and receiver (RX) is reduced significantly.

12 Claims, 1 Drawing Sheet



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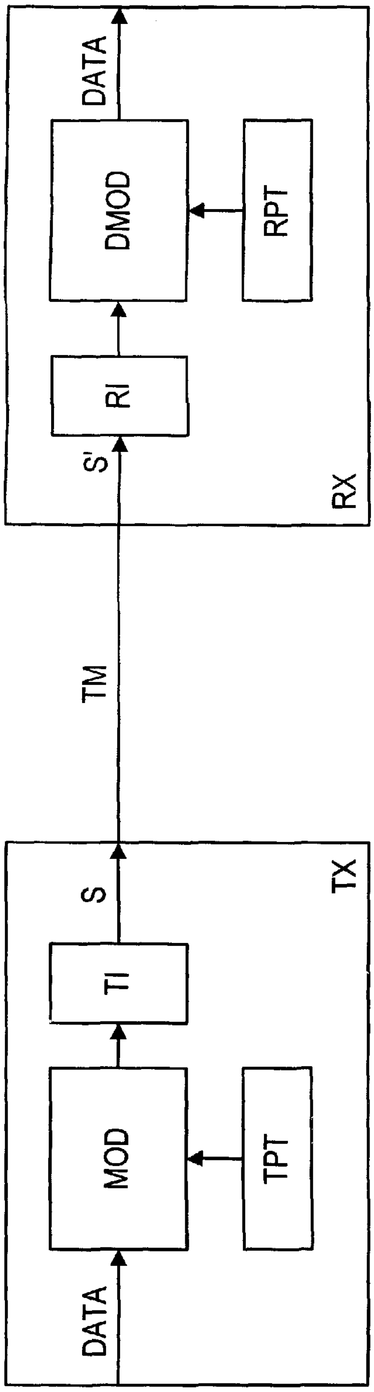
DATA
DMOD
RPT
RI
S'
RX
TM
S
TI
TX
MOD
TPT
DATA

Fig. 1

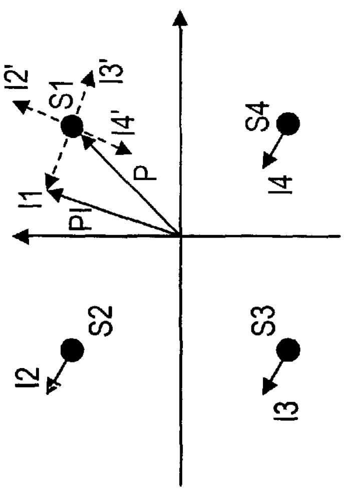
I2'
S1
I3'
I4'
P
I1
PI
S4
I4
S2
I2
S3
I3

Fig. 2

MODULATION/DEMODULATION OF A PILOT CARRIER, MEANS AND METHOD TO PERFORM THE MODULATION/ DEMODULATION

TECHNICAL FIELD

The present invention relates to a method for transmitting data elements from a transmitter to a receiver, wherein the data elements are modulated on at least one carrier; wherein a pilot carrier is used for synchronisation between the transmitter and the receiver which is multiplexed with the at least one carrier; and wherein the at least one carrier and the pilot carrier are transmitted over a transmission medium interconnecting the transmitter and the receiver.

It is also directed to a transmitter adapted to transmit data elements to a receiver via a transmission medium, the transmitter comprising modulation means to a first input of which the data elements are applied, the modulation means being adapted to modulate the data elements on at least one carrier, and to multiplex the at least one carrier with a pilot carrier used for synchronisation between the transmitter and the receiver; pilot information means, adapted to generate information to identify the pilot carrier, and to apply the information to a second input of the modulation means; and line interface means, coupled between an output of the modulation means and an input of the transmission medium and adapted to condition the at least one carrier and the pilot carrier to be transmitted over the transmission medium.

It is additionally directed to a receiver adapted to receive a signal transmitted thereto by a transmitter via a transmission medium, the receiver comprising: line interface means, coupled to an output of the transmission medium and adapted to condition the signal to be applied to components of the receiver; demodulating means, an input of which is coupled to an output of the line interface means, the demodulating means being adapted to demultiplex in the signal a pilot carrier from at least one carrier whereon data elements are modulated, and to demodulate the data elements from the at least one carrier; and pilot information means, adapted to generate information to identify the pilot carrier, and to apply the information to a second input of the demodulation means.

It is still further directed to a transmission system comprising a transmitter, a receiver and a transmission medium, coupled between an output of the transmitter and an input of the receiver, wherein the transmitter and receiver are of the above described type.

BACKGROUND OF THE INVENTION

Such a method for transmitting data elements, such a transmitter and receiver, and such a transmission system are already known in the art, e.g. from the specifications of the ANSI (*American National Standards Institute, Inc.*) Standard on ADSL, the approved version of which has the reference T1E1.413-1995 and title "*Network and Customer Installation Interfaces, Asymmetric Digital Subscriber Line* (*ADSL*) *Metallic Interface*". Therein, data elements are modulated on a set of carriers. In case of discrete multi tone (DMT) modulation, these carriers have equidistant frequencies. As is indicated in paragraphs 6.9.1.2 and 7.9.1.2 on pages 46 and 58 of the above cited standard, published in 1995, one of the carriers is reserved as a pilot carrier. This pilot carrier is used for synchronisation between transmitter and receiver and is modulated by a constant signal. In a vector plane, wherein the modulation constellation is represented by a collection of points, the pilot carrier is thus represented by a single point. On the transmission medium, e.g. on a telephone line interconnecting the ADSL transmitter and ADSL receiver in the known system, the pilot carrier thus represents a sine or cosine which does not change in phase, amplitude or frequency in time (in case a guard bond or cyclic prefix is added whose length does not contain an integer number of periods of the pilot tone, the pilot tone might be discontinuous at the edges of the DMT symbol).

A well-known source of narrowbanded or single frequency disturbances is a radio amateur or an AM radio station, which broadcasts radio signals at frequencies close to carrier frequencies. Forward error correction techniques, well-known in the art, can reduce the effect of such disturbances on data carried by the affected carriers. An alternative way to protect data against such interferers, proposed by Peter S. Chow et al. in the article "*A multicarrier E1-HDSL Transceiver System with Coded Modulation*" from the authors Peter S. Chow, Noafal Al-Dhahir, John M. Cioffi and John A. C. Bingham published in issue No. 3 May/June 1993 of the Journal of European Transactions on Telecommunications and Related Technologies (ETT), pages 257–266, is bitswapping: bit and energy allocations are updated so that the affected carriers carry less data bits then before. This technique requires an additional communication between transmitter and receiver.

Although data transmitted over the telephone line from the transmitter to the receiver may be protected by one of the above mentioned techniques, the presence of noise or an interferer, for instance a radio amateur signals with a frequency in the vicinity of the frequency of the pilot carrier, may still cause an offset between the received point representing the pilot carrier in the above defined vector plane and the expected point. If this offset in the vector plane is not sufficiently random, it biases the synchronisation mechanism, resulting in a performance degradation. This is e.g. the case if the instantaneous phase of the interferer is very slowly varying in time with respect to the duration of the DMT symbol or if this interferer is constant.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a method for transmitting data elements and related equipment of the known type, but wherein the immunity of the pilot carrier from interference is increased significantly, and consequently wherein the degradation of the synchronisation mechanism between transmitter and receiver is reduced.

According to the present invention, this object is achieved by a method for transmitting data elements from a transmitter to a receiver, wherein the data elements are modulated on at least one carrier; a pilot carrier used for synchronisation between the transmitter and the receiver is multiplexed with the at least one carrier; the at least one carrier and the pilot carrier are transmitted over a transmission medium interconnecting the transmitter and the receiver, characterized in that the pilot carrier is modulated with a non-constant signal before it is transmitted.

It is also achieved by a transmitter, adapted to transmit data elements to a receiver via a transmission medium, the transmitter comprising: modulation means to a first input of which the data elements are applied, the modulation means being adapted to modulate the data elements on at least one carrier, and to multiplex the at least one carrier with a pilot carrier used for synchronisation between the transmitter and the receiver; pilot information means, adapted to generate information to identify the pilot carrier, and to apply the information to a second input of the modulation means; and

line interface means, coupled between an output of the modulation means and an input of the transmission medium, and adapted to condition the at least one carrier and the pilot carrier to be transmitted over the transmission medium, characterised in that the modulation means is further adapted to modulate the pilot carrier with a non-constant signal.

It is still further achieved by a receiver, adapted to receive a signal transmitted thereto by a transmitter via a transmission medium, the receiver comprising line interface means, coupled to an output of the transmission medium and adapted to condition the signal to be applied to components of the receiver; demodulating means, an input of which is coupled to an output of the line interface means, the demodulating means being adapted to demultiplex in the signal a pilot carrier from at least one carrier whereon data elements are modulated, and to demodulate the data elements from the at least one carrier; and pilot information means, adapted to generate information to identify the pilot carrier, and to apply the information to a second input of the demodulation means, characterised in that the demodulating means further is adapted to demodulate a non-constant signal from the pilot carrier and to use the demodulated pilot carrier for synchronisation.

It is still further achieved by a transmission system comprising a transmitter, a receiver and a transmission medium, coupled between an output of the transmitter and an input of the receiver, the transmitter comprising: modulation means to a first input of which data elements are applied, the modulation means being adapted to modulate the data elements on at least one carrier, and to multiplex the at least one carrier with a pilot carrier used for synchronisation between the transmitter and the receiver; pilot information means, adapted to generate information to identify the pilot carrier, and to apply the information to a second input of the modulation means; and line interface means, coupled between an output of the modulation means and an input of the transmission medium, and adapted to condition the at least one carrier and the pilot carrier to be transmitted over the transmission medium, and the receiver comprising: line interface means, coupled to an output of the transmission medium and adapted to condition a signal received therefrom to be applied to components of the receiver; demodulating means, an input of which is coupled to an output of the line interface means, the demodulating mean being adapted to demultiplex in the signal the pilot carrier from the at least one carrier, and to demodulate data elements from the at least one carrier; and pilot information means, adapted to generate information to identify the pilot carrier, and to apply the information to a second input of the demodulation means, characterised in that the modulation means is further adapted to modulate the pilot carrier with a non-constant signal; and the demodulating means is adapted to demodulate the non-constant signal from the pilot carrier and to use the demodulated pilot carrier for synchronisation.

In this way, by modulating the pilot carrier with a non-constant signal, the pilot carrier appears on the transmission medium as a sine or cosine with non-constant phase and/or amplitude. Demodulation of such a pilot carrier at the receiver's side, re-generates the unmodulated pilot carrier, i.e. a sine or cosine with non varying phase and/or amplitude from the transmitted modulated pilot carrier. For interference induced on the modulated pilot carrier, this demodulation has an averaging effect as will be explained in more detail later on in the description. The effect of an interferer on different states of the modulation constellation is thus averaged by demodulation. The final effect of an interferer after demodulation is far less than the effect of the interferer on one single state in the modulation constellation scheme as a result of which the transmission system according to the present invention has a significantly increased immunity for narrowband interferers, compared to the above described known system.

It is noted that the implementation of the synchronisation means can be simplified if the constellation points of the pilot carrier are well chosen, e.g. if all points have the same amplitude.

It is further to be noticed that the term "comprising" used in the claims, should not be interpreted as being limitative to the means listed thereafter. Thus, the scope of the expression "a device comprising means A and B" should not be limited to devices consisting only of components A and B. It means that with respect to the present invention, the only relevant components of the device are A and B.

Similarly, it is to be noted that the term "coupled" also used in the claims, should not be interpreted as being limited to direct connections only. Thus, the scope of the expression "a device A coupled to a device B" should not be limited to devices or systems wherein an output of device A is directly connected to on input of device B. It means that there exists a path between an output of A and an input of B which may be a path including other devices or means.

A remark is also that, in view of the present invention, it is not important whether the frequency of the pilot carrier is a fixed one or not. The pilot carrier may change in frequency whenever the transmitter or receiver concludes that the pilot frequency is laying within a frequency bond with too much interference. The transmitter and receiver then have to negotiate a new pilot tone frequency More details about this technique are irrelevant in view of the present invention but it is stressed here that changing the frequency of the pilot tone and modulating the pilot tone with non-constant signals are two techniques which may be applied independently to improve interference immunity of the synchronisation between transmitter and receiver. These techniques may be used complementary or may be applied separately.

In a particular implementation of the present invention, the pilot carrier is modulated as a random or pseudo-random signal.

In this way, by modulating a randomised signal on the pilot carrier, the state of the pilot carrier in the constellation scheme will change randomly so that the demodulation will have a good averaging effect resulting in an increase of the interference immunity.

In another implementation of the present invention, the pilot carrier is modulated with a predefined sequence that ensures sufficient alternations of the states of the pilot carrier.

In this way, if the averaged effect of interference over all visited states in the constellation scheme is zero after demodulation, the best results will be obtained in terms of improvement of the interference immunity. Indeed, when each state has an equal probability and the constellation has a symmetry around zero, the effect of interference will be compensated for completely after demodulation. As an example, the constellation might contain only two points with the same amplitude but with opposite phases. Successive pilots would then have alternate phases.

It is remarked that the proposed technique con be used whether or not the predefined sequence is known at the receiver. If the sequence is unknown, the receiver has to demap the received pilot, i.e. it has to map the received point on a constellation point. The decision is then used to generate the unmodulated pilot.

In yet another implementation of the present invention, the pilot carrier is modulated part of the data elements to be transmitted.

This implementation has the additional advantage that it provides an enlarged bandwidth for transport of data elements. Indeed, in the already cited ADSL system for instance, the pilot carrier may be modulated with an 8 kbit/s datastream by allocating two bits to it. If this additional bandwidth is used for transporting data elements, the aggregate bit rate between transmitter and receiver will be increased with an equivalent amount. It is to be remarked that, to have significant immunity against interferers, the data elements which are modulated on the pilot carrier, hove to be sufficiently random so that the pilot carrier reaches all states in the constellation scheme and a good averaging of the interference is obtained by demodulation. This can be obtained by scrambling.

An additional feature of the present invention is that it may be applied in the field of ADSL and VDSL so that the transmitter and receiver constitute a discrete multitone transceiver according to the Asymmetric Digital Subscriber Line standard T1E1.413.

Indeed, systems wherein data elements are transmitted over copper telephone lines such as ADSL (Asymmetric Digital Subscriber Line), VDSL (Very High Bitrate Digital Subscriber Line) or the like are subjected to interference such as radio amateur signals. It is therefore likely to protect such systems with the technique according to the present invention.

Furthermore, a characteristic feature of the present invention is where the data elements modulated on the pilot carrier are operation channel data elements or overhead control channel data elements such as data elements used for maintenance or indicating a modification of the number of bits modulated on a carrier of the at least one carrier.

As described in the already mentioned ADSL specification, the DMT symbols contain user data and overhead data, e.g. operation channel data or overhead control channel data such as operation and maintenance commands, vendor specific commands, bit swap information, and so on. The embedded operations channel (eoc) and the ADSL overhead control (aoc) channel are described respectively in paragraphs 11.1 13.1 on pages 71 and 112 of the earlier mentioned specification. This information may for instance be modulated on the pilot carrier.

BRIEF DESCRIPTION OF THE DRAWINGS

The above mentioned and other objects and features of the invention will become more apparent and the invention itself will be best understood by referring to the following description of an embodiment taken in conjunction with the accompanying drawings wherein:

FIG. **1** represents a transmission system including a transmitter TX and a receiver RX according to the present invention; and

FIG. **2** represents a constellation scheme for modulating a pilot carrier in a particular embodiment of the present invention, and illustrates the influence of interference induced on the modulated pilot carrier.

BEST MODE FOR CARRYING OUT THE INVENTION

The transmission system drawn in FIG. **1** includes a first Asymmetric Digital Subscriber Line (ADSL) modem of which only the transmitting part TX **20** is drawn, a second ADSL modem of which only the receiving part RX **30** is drawn, and a copper twisted pair telephone line TM **40** coupling the two ADSL modems. The first ADSL modem may for instance be located in a remote terminal and modulates data DATA **21** to be transmitted over the telephone line TM **40** towards the second ADSL modem which may for instance be located in a central office. Both ADSL modems respect the specifications of the ADSL Standard T1E1.413.

The transmitting part TX **20** of the first ADSL modem contains between a data input DATA **21** and a signal output S **25** the cascade connection of a discrete multitone (DMT) modulator MOD **22** and a line interface TI **24**. In addition, pilot tone identifying means TPT **26** are included and have an output coupled to an additional input of the DMT modulator MOD **22**.

The receiving port RX **30** of the second ADSL modem contains between a signal input S' **35** and a data output DATA' **37** the cascade connection of a line interface RI **32** and a discrete multitone (DMT) demodulator DMOD **34**. In addition, pilot tone identifying means RPT **36** are included and have an output coupled to an additional input of the DMT demodulator DMOD **34**.

In FIG. **1**, an embodiment of the transmission system according to the present invention is thus drawn in terms of functional blocks: TX, RX, TM, MOD, TI, TPT, RI, DMOD and RPT. The working of each of these blocks will be described sufficiently detailed in the following paragraphs. From this functional description, it will be obvious for a person skilled in the art of designing telecommunication devices how embodiments of these blocks can be manufactured with well-known electronic components. A detailed architecture of the contents of the functional blocks drawn in FIG. **1** hence is not given here.

In the transmitting part TX of the first ADSL modem, data DATA are applied to a data input DATA of the modulator MOD to be modulated thereby on a set of carriers. It is noticed that in FIG. **1**, the some reference DATA is used for the incoming data and the terminal of the modulator MOD where the data are applied to. Furthermore it is remarked that the applied data DATA may be user data received from the outside world as well as overhead data, for instance bit allocation information generated inside the first ADSL modem. The modulator MOD then performs bit allocation, i.e. the modulator MOD allocates a certain number of data bits to each one of the carriers, selects an appropriate modulation type for each one of the carriers so that the right amount of bits can be modulated thereon, and then modulates the carriers. The carriers are transformed from frequency to time domain by the modulator MOD and extended cyclically so as to minimise intersymbol interference effects due to transmission over the telephone line TM. The so obtained symbols, called discrete multitone symbols, contain one carrier which is assigned to be pilot carrier and which will be used at the receiver's side for synchronisation. The modulator MOD modulates this pilot carrier in an alternating way. This means that, when 2 bits can be modulated on the pilot carrier via 4 QAM modulation, 4 different states are transmitted in an alternating way. The 4 states of the 4 QAM modulation technique are drawn in FIG. **2** and represented there by **S1**, S2, **S3** and S4. Each of these states corresponds to a sine wave signal on the transmission line TM, and has its particular phase and amplitude. The frequency of this sine wave signal is defined by the pilot tone information means TPT. The pilot tone information means TPT may for example be a simple register containing on indication of the fixed frequency of the pilot tone, or

alternatively, may be a device negotiating with the pilot tone information means RPT in the second modem which frequency will be reserved for the pilot tone. Modulating the pilot carrier in an alternating way implies that in successive DMT symbols, the pilot carrier is represented by sine waves **S1**, **S2**, **S3**, **S4**, **S1**, **S2**, . . . , and so on, or by another (predefined) sequence that visits all states in an alternating way. This is different from what is specified in the draft ADSL standard. Therein, the pilot carrier should be modulated With a constant signal, e.g. (0,0) which may be represented by the point in the first quadrant of the earlier mentioned vector plane in case of 4 QAM modulation. This means that on ADSL modem, operating according to the ADSL standard, transmits one single sine, **S1** for instance, in successive DMT symbols as the pilot carrier.

In FIG. **2** it is supposed that a radio amateur signal affects the pilot tone carrier in the above described embodiment according to the present invention. The interference component added to the states **S1**, **S2**, **S3** and **S4** in successive DMT symbols is **11**, **12**, **13** and **14** respectively. Instead of a sine wove whose amplitude and phase is determined by the vector P in FIG. **2**, the receiver RX thus receives a sine wave whose amplitude and phase correspond to that of PI. Similarly, the sine wave received by the receiver RX in symbols wherein states **S2**, **S3**, or **S4** are transmitted, differs in phase and amplitude from the transmitted sine wave in an amount determined by the respective vectors **12**, **13** and **14**.

The affected signal S' enters the receiving part RX of the central office modem and is applied to the line interface RI to be conditioned: transmission line coupling, front-end filtering and analogue to digital conversion for instance are performed with the appropriate levels of linearity and noise in RI. The conditioned and digitised signal then is applied to the demodulator DMOD which equalises the signal in time domain to compensate for intersymbol interference, which removes the cyclic prefix, converts the time domain signal into a frequency domain signal via fast fourier transformation and equalises the signal in frequency domain to compensate for phase and amplitude errors in the received carriers. The demodulator DMOD also regenerates the pilot carrier from the successive states **S1**, **S2**, **S3**, **S4**. The demodulation thereto leaves **S1** unaffected, rotates **S2** in the next DMT symbol over 90 degrees clockwise, rotates **S3** in the next DMT symbol over 180 degrees clockwise, rotates **S4** in the next DMT symbol over 270 degrees clockwise, and so on. All states are thus rotated to the first quadrant so that a continuous pilot carrier at the frequency indicated by the pilot frequency indicating means RPT is constituted. Due to the interference **11**, **12**, **13** and **14** induced on **S1**, **S2**, **S3** and **S4** respectively, the sine wave in successive DMT symbols representing the pilot carrier, differs in phase and amplitude from the originally transmitted phase and amplitude determined by the vector P. When turned back to the first quadrant, the phase and amplitude of the sine waves received in successive DMT symbols is given by the vectors P+11, P+12', P+13' and P+14'. As is seen from FIG. **2**, the interference component induced on **S1**, i.e. 11, compensates for the interference effect **13**' for the interference effect **14**' induced on **S4**. Regenerating the pilot carrier in the demodulation DMOD and averaging over successive DMT symbols thus reduces the effect of the interference, if the pilot carrier is transmitted over the transmission line TM as a sequence of alternating modulation states. Theoretically, the pilot carrier can be regenerated perfectly so that synchronisation between the transmitter TX and receiver RX is not disturbed by the radio amateur. As a consequence, the data DATA' can be retrieved by demodulation of the other carriers in a perfect way.

A first remark is that, although the signal S in the above described embodiment is transported over a telephone line TM, the applicability of the present invention is not restricted by the transmission medium via which the signal S is transported. In particular, any connection between the transmitter TX and receiver RX, e.g. a cable connection, a satellite connection, a radio link through the air, and so on, may be affected by norrowbanded interference, and thus can be protected by the method according to the present invention. The invention also is not only related to ADSL (Asymmetric Digital Subscriber Line) or similar systems wherein DMT (Discrete Multi Tone) modulation is used. A person skilled in the art will be able to adopt the above described embodiment so that it is applicable to any other system wherein a pilot carrier is transmitted from transmitter TX to receiver RX for synchronisation purposes. U.S. Pat. No. 5,546,190 for instance describes an optical communication system wherein a pilot tone is multiplexed with multiple subcarriers, having frequencies which are integer multiples of the pilot tone frequency, and U.S. Pat. No. 5,548,344 describes an HDTV system wherein a pilot sine wave signal is multiplexed with the HDTV carriers.

Another remark is that the origin of the narrowbanded interference is of no importance for applicability of the present invention. Whether the disturbing signals are transmitted by a radio amateur, as supposed in the above described example, by a taxi, by the police, or are originating from yet another source is not relevant. Whenever the transmitter TX expects that the pilot carrier may be affected by an interferer, he can protect the synchronisation between transmitter TX and receiver RX by modulating the pilot carrier.

It is noticed that in an alternative embodiment, the pilot tone is modulated randomly instead of in an alternating way. This means that, referring to FIG. **2**, a random sequence of the states **S1**, **S2**, **S3** and **S4** is transmitted instead of a predetermined alternating sequence.

In yet another alternative embodiment, the pilot carrier may be modulated with scrambled data. Scrambling part of the data DATA in FIG. **1** has a randomising effect. Such randomised data then may be modulated on the pilot carrier. Since the states **S1**, **S2**, **S3** and **S4** will randomly be transmitted, demodulation in the receiver and averageing will again reduce the effect of the induced interference. Apparently, the latter embodiment has the advantage of an increased capacity, since the bandwidth occupied by the pilot carrier also is used for transmission of data. In case of ADSL transmission, overhead information such as the aoc-data or eoc-data may be used to modulate the pilot carrier.

While the principles of the invention have been described above in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation on the scope of the invention.

What is claimed is:

1. A method for transmitting data elements (DATA) from a transmitter (TX) to a receiver (RX), wherein

a. said data elements (DATA) modulate on at least one carrier;

b. a pilot carrier used for synchronisation between said transmitter (TX) and said receiver (RX) is multiplexed with said at least one carrier;

c. said at least one carrier and said pilot carrier are transmitted over a transmission medium (TM) interconnecting said transmitter (TX) and said receiver (RX), characterized

in that said pilot carrier is modulated with a non-constant signal before it is transmitted so as to produce a pilot carrier having a sine or cosine waveform with non-constant phase and/or amplitude wherein said non-constant signal consists of part of said data elements (DATA) to be transmitted for enlarging bandwidth for transport of said data element, and

d. said part of said data elements is sufficiently random in time thereby improving immunity of said pilot carrier to interference.

2. A method according to claim **1**, characterised in that said non-constant signal is a random or pseudo-random signal.

3. A method according to claim **1**, characterised in that said non-constant signal is an alternating signal, subsequently alternating between different states of the modulation constellation.

4. A method according to claim **1**, characterised in that said transmitter (TX) and said receiver (RX) constitute a discrete multitone (DMT) transceiver according to the Asymmetric Digital Subscriber Line standard T1E1.413.

5. A method according to claim **1**, characterized in that said data elements (DATA) modulated on said pilot carrier are operation channel data elements or overhead control channel data elements such as data elements used for maintenance or indicating a modification of the number of bits modulated on a carrier of said at least one carrier.

6. The method of claim **1**, wherein said data elements include user data.

7. A transmitter (TX), adapted to transmit data elements (DATA) to a receiver (RX) via a transmission medium (TM), said transmitter (TX) comprising:

a. modulation means (MOD) to a first input of which said data elements (DATA) are applied, said modulation means (MOD) being adapted to modulate said data elements (DATA) on at least one carrier, and to multiplex said at least one carrier with a pilot carrier used for synchronisation between said transmitter (TX) and said receiver (RX); and

b. line interface means (TI), coupled between an output of said modulation means (MOD) and an input of said transmission medium (TM), and adapted to condition said at least one carrier and said pilot carrier to be transmitted over said transmission medium (TM), characterised in that said modulation means (MOD) is further adapted to modulate said pilot carrier with a non-constant signal so as to produce a pilot carrier having a sine or cosine waveform with non-constant phase and/or amplitude wherein said non-constant signal consists of part of said data elements (DATA) to be transmitted for enlarging bandwidth for transport of said data elements, and said part of said data elements is sufficiently random in time thereby improving immunity of said pilot carrier to interference.

8. The transmitter of claim **7**, wherein said data elements include user data.

9. A receiver (RX), adapted to receive a signal (S') transmitted thereto by a transmitter (TX) via a transmission medium (TM), said receiver (RX) comprising:

a. line interface means (RI), coupled to an output of said transmission medium (TM) and adapted to condition and signal (S') to be applied to components of said receiver (RX); and

b. demodulating means (DMOD), an input of which is coupled to an output of said line interface means (RI), said demodulating means (DMOD) being adapted to demultiplex in said signal (S') a pilot carrier from at least one carrier modulated with data elements (DATA'), and to demodulate said data elements (DATA') from said at least one carrier, characterised in that said pilot carrier is modulated with a non-constant signal so as to produce a sine or cosine waveform with non-constant phase and/or amplitude wherein said non-constant signal consists of part of said data elements (DATA) to be transmitted for enlarging bandwidth for transport of said data elements, wherein said part of said data elements is sufficiently random in time thereby improving immunity of said pilot carrier to interference, and said demodulating means (DMOD) further is adapted to demodulate the non-constant signal from said pilot carrier and to use the demodulated pilot carrier for synchronisation.

10. The receiver of claim **9**, wherein said data elements include user data.

11. A transmission system comprising a transmitter (TX), a receiver (RX) and a transmission medium (TM), coupled between an output of said transmitter (TX) and an input of said receiver (RX), said transmitter (TX) comprising:

a. modulation means (MOD) to a first input of which data elements (DATA) are applied, said modulation means (MOD) being adapted to modulate said data elements (DATA) on at least one carrier, and to multiplex said at least one carrier with a pilot carrier used for synchronisation between said transmitter (TX) and said receiver (RX); and

b. line interface means (TI), coupled between an output of said modulation means (MOD) and an input of said transmission medium (TM), and adapted to condition said at least one carrier and said pilot carrier to be transmitted over said transmission medium (TM), and said receiver (RX) comprising:

c. line interface means (RI), coupled to an output of said transmission medium (TM) and adapted to condition a signal (S') received therefrom to be applied to components of said receiver (RX); and

d. demodulating means (DMOD), an input of which is coupled to an output of said line interface means (RI), said demodulating means (DMOD) being adapted to demultiplex in said signal (S') said pilot carrier from said at least one carrier, and to demodulate data elements (DATA') from said at least one carrier, characterized in that said modulation means (MOD) is further adapted to modulate said pilot carrier with a non-constant signal so as to produce a sine or cosine waveform with non-constant phase and/or amplitude wherein said non-constant signal consists of part of said data element (DATA) to be transmitted for enlarging bandwidth for transport of said data elements, wherein said part of said data elements is sufficiently random in time thereby improving immunity of said pilot carrier to interference, and said demodulating means (DMOD) is adapted to demodulate said non-constant signal from said pilot carrier and to use the demodulated pilot carrier for synchronisation.

12. The transmission system of claim **11**, wherein said data elements include user data.

* * * * *

IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

TQ DELTA, LLC, Plaintiff, v. COMCAST CABLE COMMUNICATIONS, LLC Defendant.	Civil Action No. 1:15-cv-00611-RGA
TQ DELTA, LLC, Plaintiff, v. COXCOM LLC and COX COMMUNICATIONS INC., Defendants.	Civil Action No. 1:15-cv-00612-RGA
TQ DELTA, LLC, Plaintiff, v. DIRECTV, LLC, Defendant.	Civil Action No. 1:15-cv-00613-RGA

TQ Delta Exhibit 2007
Cisco Systems, Inc. v. TQ Delta LLC
IPR2016-01020

TQ DELTA, LLC, Plaintiff, v. DISH NETWORK CORPORATION, DISH NETWORK LLC, DISH DBS CORPORATION, ECHOSTAR CORPORATION, and ECHOSTAR TECHNOLOGIES, LLC Defendants.	Civil Action No. 1:15-cv-00614-RGA
TQ DELTA, LLC, Plaintiff, v. TIME WARNER CABLE INC. and TIME WARNER CABLE ENTERPRISES LLC, Defendants.	Civil Action No. 1:15-cv-00615-RGA
TQ DELTA, LLC, Plaintiff, v. VERIZON SERVICES CORP., Defendant.	Civil Action No. 1:15-cv-00616-RGA

MEMORANDUM OPINION

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November 30, 2016

ANDREWS, U.S. DISTRICT JUDGE:

Presently before the Court is the issue of claim construction of multiple terms in U.S. Patent Nos. 8,718,158 ("the '158 patent"), 9,014,243 ("the '243 patent"), 8,611,404 ("the '404 patent"), 9,094,268 ("the '268 patent"), 7,835,430 ("the '430 patent"), and 8,238,412 ("the '412 patent"). The Court has considered the Parties' Joint Claim Construction Brief. (Civ. Act. No. 15-611-RGA, D.I. 144; Civ. Act. No. 15-612-RGA, D.I. 141; Civ. Act. No. 15-613-RGA, D.I. 141; Civ. Act. No. 15-614-RGA, D.I. 135; Civ. Act. No. 15-615-RGA, D.I. 141; Civ. Act. No. 15-616-RGA; D.I. 146).[1] The Court heard oral argument on October 18, 2016. (D.I. 158).

I. BACKGROUND

Plaintiff filed these actions on July 17, 2015, alleging infringement of eight patents. (D.I. 1). On July 14, 2016, Plaintiff dismissed two of these patents with prejudice. (D.I. 102). The parties divide the remaining contested patents into three groupings: the phase scrambling patents, the low power mode patents, and the diagnostic mode patents. The phase scrambling patents, which include the '158 and '243 patents, claim methods for reducing the peak to average power ratio of a multicarrier transmission system. The low power mode patents, which include the '404 and '268 patents, claim methods for causing a multicarrier communications system to enter a low power mode while storing state information for full power mode to enable a rapid start up without the need for reinitialization. The diagnostic mode patents, which include the '430 and '412 patents, claim both an apparatus and method for the reliable exchange of diagnostic and test information over a multicarrier communications system.

[1] Unless otherwise specifically noted, all references to the docket refer to Civil Action No. 15-611-RGA.

II. LEGAL STANDARD

"It is a bedrock principle of patent law that the claims of a patent define the invention to which the patentee is entitled the right to exclude." *Phillips v. AWH Corp.*, 415 F.3d 1303, 1312 (Fed. Cir. 2005) (en banc) (internal quotation marks omitted). "'[T]here is no magic formula or catechism for conducting claim construction.' Instead, the court is free to attach the appropriate weight to appropriate sources 'in light of the statutes and policies that inform patent law.'" *SoftView LLC v. Apple Inc.*, 2013 WL 4758195, at *1 (D. Del. Sept. 4, 2013) (quoting *Phillips*, 415 F.3d at 1324) (alteration in original). When construing patent claims, a court considers the literal language of the claim, the patent specification, and the prosecution history. *Markman v. Westview Instruments, Inc.*, 52 F.3d 967, 977–80 (Fed. Cir. 1995) (en banc), *aff'd*, 517 U.S. 370 (1996). Of these sources, "the specification is always highly relevant to the claim construction analysis. Usually, it is dispositive; it is the single best guide to the meaning of a disputed term." *Phillips*, 415 F.3d at 1315 (internal quotation marks omitted).

"[T]he words of a claim are generally given their ordinary and customary meaning. . . . [Which is] the meaning that the term would have to a person of ordinary skill in the art in question at the time of the invention, i.e., as of the effective filing date of the patent application." *Id.* at 1312–13 (citations and internal quotation marks omitted). "[T]he ordinary meaning of a claim term is its meaning to [an] ordinary artisan after reading the entire patent." *Id.* at 1321 (internal quotation marks omitted). "In some cases, the ordinary meaning of claim language as understood by a person of skill in the art may be readily apparent even to lay judges, and claim construction in such cases involves little more than the application of the widely accepted meaning of commonly understood words." *Id.* at 1314.

When a court relies solely upon the intrinsic evidence—the patent claims, the specification, and the prosecution history—the court's construction is a determination of law. *See Teva Pharm. USA, Inc. v. Sandoz, Inc.*, 135 S. Ct. 831, 841 (2015). The court may also make factual findings based upon consideration of extrinsic evidence, which "consists of all evidence external to the patent and prosecution history, including expert and inventor testimony, dictionaries, and learned treatises." *Phillips*, 415 F.3d at 1317–19 (internal quotation marks omitted). Extrinsic evidence may assist the court in understanding the underlying technology, the meaning of terms to one skilled in the art, and how the invention works. *Id.* Extrinsic evidence, however, is less reliable and less useful in claim construction than the patent and its prosecution history. *Id.*

"A claim construction is persuasive, not because it follows a certain rule, but because it defines terms in the context of the whole patent." *Renishaw PLC v. Marposs Societa' per Azioni*, 158 F.3d 1243, 1250 (Fed. Cir. 1998). It follows that "a claim interpretation that would exclude the inventor's device is rarely the correct interpretation." *Osram GMBH v. Int'l Trade Comm'n*, 505 F.3d 1351, 1358 (Fed. Cir. 2007) (citation and internal quotation marks omitted).

III. CONSTRUCTION OF DISPUTED TERMS

A. The Phase Scrambling Patents

The '158 patent is directed to a method for scrambling the phase characteristics of carrier signals in a multicarrier communications system. Claim 1 is representative and reads as follows:

> 1. In a *multicarrier* modulation system including a first *transceiver* in communication with a second *transceiver* using a transmission signal having a plurality of *carrier signals* for modulating a plurality of data bits, each *carrier signal* having a phase characteristic associated with at least one bit of the plurality of data bits, a method for *scrambling the phase characteristics of the carrier signals* comprising:
>
> transmitting the plurality of data bits from the first *transceiver* to the second *transceiver*;

> associating a *carrier signal* with a value determined independently of any bit of the plurality of data bits carried by the *carrier signal*, the value associated with the *carrier signal* determined by a pseudo-random number generator;
>
> *determining a phase shift for the carrier signal* at least based on the value associated with the *carrier signal*;
>
> modulating at least one bit of the plurality of data bits on the *carrier signal*;
>
> modulating the at least one bit on a second *carrier signal* of the plurality of *carrier signals*.

('158 patent, claim 1) (disputed terms italicized).

The '243 patent is also directed to a method for scrambling the phase characteristics of carrier signals in a multicarrier communications system. Claim 1 is representative and reads as follows:

> 1. A method, in a *multicarrier* communications *transceiver* comprising a *bit scrambler* followed by a *phase scrambler*, comprising:
>
> scrambling, using the *bit scrambler*, a plurality of input bits to generate a plurality of scrambled output bits, wherein at least one scrambled output bit is different than a corresponding input bit;
>
> scrambling, using the *phase scrambler*, a plurality of *carrier* phases associated with the plurality of scrambled output bits;
>
> transmitting at least one scrambled output bit on a first *carrier*; and
>
> transmitting the at least one scrambled output bit on a second *carrier*.

('243 patent, claim 1) (disputed terms italicized).

1. "carrier signal" and "carrier"

    a. *Plaintiff's proposed construction*: "plain meaning"

    b. *Defendants' proposed construction*: "wave that can be modulated to carry data"

    c. *Court's construction*: "signal that can be modulated to carry data"

The parties agree that "carrier signal" and "carrier" should have the same construction. (D.I. 144 at 36). Defendants argue strenuously that the proper construction for this term requires that the carrier signal be a wave and that this construction is supported by the specification itself. (*Id.* at 33). Contrary to Defendants' assertion, however, neither "wave" nor "waveform" appear anywhere in the specification. To require that the carrier be a wave, therefore, would be to import

a term that itself requires construction. Plaintiff argues that the wave Defendants refer to throughout their briefing and during oral argument is simply the time domain representation of a signal that exists only after the carrier signals are modulated and combined. (*Id.* at 21, 33, 35; D.I. 158 at 70:12-18). The specification supports Plaintiff's position, describing the carrier signals as being modulated in the frequency domain prior to being combined into the time domain transmission signal. ('158 patent at 4:12-24). While I find support for Plaintiff's opposition to using the word "wave" in the construction of this term, I agree with Defendants that some construction is needed, so I will adopt Defendants' construction modified as follows: "signal that can be modulated to carry data."

2. "determin[e/ing] a phase shift for the carrier signal"

   a. *Plaintiff's proposed construction*: "plain meaning"

   b. *Defendants' proposed construction*: "use/using an equation to compute the degrees or radians that the phase of the carrier signal can be shifted"

   c. *Court's construction*: "comput[e/ing] an amount by which the phase of the carrier signal will be shifted"

As an initial matter, the parties disagree as to whether the phase shift must be determined in units of degrees or radians. There is no support in the intrinsic record for Defendants' attempt to import these terms into the claim. Degrees and radians are merely units of measure, akin to feet or meters. I see no reason to limit this claim term to require specific units of measure for the phase shift.

Defendants next argue that this term should be construed to limit the meaning of "determine" to mean compute. Defendants cite the invention as described in the "Summary of the Invention" section of the specification as support and argue that the invention as a whole is described using the word "compute" with respect to how the phase shift is determined. (D.I. 144

at 38). I agree with Defendants. The specification, in describing the "present invention," states that "[a] phase shift is computed for each carrier signal." ('158 patent at 2:39-40). Every reference to the phase shift in the Summary of the Invention section reflects that the shift is "computed." *See id.* at 2:43, 2:58-59, 2:63-64. "When a patent thus describes the features of the 'present invention' as a whole, this description limits the scope of the invention." *Verizon Servs. Corp. v. Vonage Holdings Corp.*, 503 F.3d 1295, 1308 (Fed. Cir. 2007).

Defendants further argue that "by definition, to 'compute' is to use an equation." (D.I. 144 at 39). Plaintiff counters that the definition of compute is broader and that Defendants are "attempting to import a limitation from an example embodiment." (*Id.* at 39-40). On this point I agree with Plaintiff. Although the example embodiments do employ an equation to compute the phase shifts, the specification disclaims reliance on any particular method, stating that "additional and/or different phase shifting techniques can be used by the phase scrambler." ('158 patent at 8:14-15). Defendants also cite to the provisional application as further support for their argument; however, the provisional application also disclaims reliance on any particular method for determining the phase shifts, stating that "[t]he fundamental principle used in this invention is to use known parameters at the transmitter and the receiver to randomize the phase of the tones in a multicarrier system." (D.I. 146 at A355).

Therefore, I decline to adopt either Plaintiff's or Defendants' proposed constructions. Instead I construe the term "determin[e/ing] a phase shift for the carrier signal" to mean "comput[e/ing] an amount by which the phase of the carrier signal will be shifted."

3. "phase scrambler"

a. *Plaintiff's proposed construction*: "a component operable to adjust the phases of the carriers, by pseudo-randomly varying amounts"

b. *Defendants' proposed construction*: "component that adjusts the phases of modulated carrier signals by pseudo-randomly varying amounts"

c. *Court's construction*: "component operable to adjust the phases of the carrier signals, by pseudo-randomly varying amounts"

"scrambling the phase characteristics of the carrier signals"

a. *Plaintiff's proposed construction*: "adjusting the phase characteristics of the carrier signals by pseudo-randomly varying amounts"

b. *Defendants' proposed construction*: "adjusting the phases of the modulated carrier signals by pseudo-randomly varying amounts"

c. *Court's construction*: "adjusting the phase characteristics of the carrier signals by pseudo-randomly varying amounts"

The parties' only dispute with respect to these two claim terms is whether the carrier signals are modulated before or after phase scrambling occurs. Plaintiff argues that in every embodiment disclosed in the specification phase scrambling occurs before modulation. (D.I. 144 at 42). Defendants counter that the specification requires "adding phase shifts to modulated carrier signals." (*Id.* at 43). I find that Plaintiff's position is supported by the patent. For example, the specification describes the process that takes place in the transmitter as "adjusting the phase characteristic of each carrier signal and combining these carrier signals to produce the transmission signal." ('158 patent, 5:16-19). The specification also provides descriptions of several different phase shifting examples, and then states, "The DMT transmitter 22 then combines (step 130) the carrier signals to form the transmission signal 38." (*Id.* at 8:17-19). Defendants' attempt to parse phrases such as "method that scrambles the phase characteristics of the modulated carrier signals in a transmission signal" to require that the signals be modulated before phase scrambling is unavailing. (D.I. 144 at 48-49). This phrase, taken from the Summary of the Invention, is nothing more than a high-level description of the transmission signal as being composed of modulated carrier signals whose phases have been scrambled. Nothing in the claims or the descriptions of

example embodiments supports Defendants' argument that the phase scrambling occurs after modulation. I will adopt Plaintiff's construction.

4. "transceiver"

a. *Plaintiff's proposed construction*: "a communications device capable of transmitting and receiving data over the same physical medium wherein the transmitting and receiving functions are implemented using at least some common circuitry"

b. *Defendants' proposed construction*: "communications device with a transmitter and receiver"

c. *Court's construction*: "communications device capable of transmitting and receiving data wherein the transmitter portion and receiver portion share at least some common circuitry"

This term appears in all six of the asserted patents and the parties agree that the term should have the same construction in each claim. (D.I. 144 at 22). The parties also agree that a transceiver is a device that can both transmit and receive data. The parties dispute, however, whether the transmission and reception must occur over the same physical medium, *e.g.*, over cable or air, and whether the transmitter and receiver components of the transceiver must share common circuitry. As to the first point of dispute, there is no support in either the intrinsic or extrinsic record for the limitation that the transmission and reception of data occur over the same physical medium. Plaintiff cites only to an expert declaration to support its contention that a person of ordinary skill in the art would understand that the transmitting and receiving must occur over the same physical medium. (D.I. 144 at 25). However, nothing in the claims or specification supports this construction and Plaintiff has not pointed to any dictionary definitions or evidence other than the expert declaration to support its construction. I decline to import this limitation into the claim term.

As to the common circuitry limitation, the only information to be gleaned from the claim language itself is that the transceiver contemplated by these patents must be able to both transmit and receive data. (*See, e.g.*, '158 patent, claim 1). The specifications do not provide an explicit definition of transceiver. In the phase scrambling patents, the specification and figures indicate that the transceiver as described is a singular device housing both a transmitter portion and a receiver portion. (*Id.* at 3:31-33). These patents do not provide any specific indication that any circuitry is shared between the two. In the low power mode patents, however, the specification and figure do indicate the presence of shared components. For example, the clock, controller, and frame counter are shared by the transmitter and receiver portions of the transceiver. ('404 patent at Fig. 1).

The parties provide five different dictionary definitions for transceiver, three of which include a limitation that the transmitter and receiver share common circuitry. (D.I. 146 at A423, A433, A444, A891, A938-39). Evaluating the intrinsic evidence in light of these dictionary definitions suggests that the transmitter and receiver portions do share common circuitry or components. Therefore, I will construe transceiver to mean "a communications device capable of transmitting and receiving data wherein the transmitter portion and receiver portion share at least some common circuitry."

5. "multicarrier"

   a. *Plaintiff's proposed construction*: "having multiple carrier signals that are combined as a group by simultaneous modulation to produce a transmission signal"

   b. *Defendants' proposed construction*: "having multiple carrier signals that are combined to produce a transmission signal"

   c. *Court's construction*: "having multiple carrier signals that are combined to produce a transmission signal"

The parties' only disagreement is whether this term should be construed to specify a particular method by which the carrier signals are combined. Plaintiff's opposition to Defendants' broader construction appears to stem from its disagreement with Defendants' proposed construction of "carrier." (D.I. 158 at 30:20-31:7). Since I have rejected Defendants' proposed limitations on "carrier," this concern is unwarranted. As discussed above, I have concluded that the patents disclose combination and modulation of carrier signals in the frequency domain, that is, before a time domain signal, or wave, exists. Turning to Plaintiff's proposed limitation, I find that the claim language itself does not impose any limitation on how the carrier signals are to be combined. Nor does the specification provide such limitations. Therefore, I will adopt Defendants' proposed construction.

6. "bit scrambler"

a. *Plaintiff's proposed construction*: "a component that pseudo-randomly changes the value of a bit"

b. *Defendants' proposed construction*: "component that pseudo-randomly inverts the bits in a byte of data one bit after another"

c. *Court's construction*: "component that pseudo-randomly changes the value of a bit"

The parties disagree on two points in their proposed constructions of this term: first, whether the bit scrambler operates on a byte of data; and second, whether the bits are scrambled in sequence, one after another. The parties' disagreement appears to center around whether a person of ordinary skill in the art would find that a bit scrambler is different from a byte scrambler. I do not think it is necessary to resolve this disagreement as the patent itself provides sufficient guidance as to the meaning of "bit scrambler."

The word "byte" does not appear in either the claims or specification of the '243 patent. The patent refers to "scrambling, using the bit scrambler, a plurality of input bits." ('243 patent,

claim 1). A plurality of input bits simply means more than one input bit. A byte of data is commonly understood to consist of eight bits of data. *See, e.g.*, OXFORD ENGLISH DICTIONARY (2d ed. 1989), *available at* http://www.oed.com/oed2/00030648 (defining byte as "[a] group of eight consecutive bits operated on as a unit in a computer"). There is no basis in the claim itself or in the specification for requiring that the "plurality of input bits" consist of a byte, or eight bits, of data. Nor is there any indication in the patent that the data must be presented to the scrambler a byte at a time. Rather, as Defendants themselves point out, the data is presented a bit at a time. Defendants cite the ADSL standards as extrinsic evidence of what a person of ordinary skill would understand a "bit scrambler" to be. (D.I. 144 at 52-53). The device described in the standards, however, is simply called a "scrambler," not a "bit scrambler." (D.I. 145 at A503). Furthermore, the standards show that data is input to this scrambler a byte at a time, not as a serial bit stream. (*Id.*). This is inconsistent with the bit scrambler described in the specification.

As to Defendants' argument that the scrambling must be performed sequentially, the claim language does not support such a limitation. The claim itself is indifferent to whether the scrambling is sequential, stating that the bit scrambler scrambles "a plurality of input bits to generate a plurality of output bits." (*Id.*). The specification states that the bit scrambler "receives the input serial bit stream" and, after scrambling, passes the bits to the QAM encoder. (*Id.* at 5:6-9). The QAM encoder is described as "receiving an input serial data bit stream." (*Id.* at 3:63-64). This seems to indicate that the input and output of the bit scrambler are both serial. This does not mean, however, that the scrambling itself necessarily takes place sequentially. Therefore, the intrinsic evidence does not support Defendants' proposed limitations and I will adopt Plaintiff's construction.

B. The Low Power Mode Patents

The '404 patent is directed to a multicarrier transmission system with low power sleep mode and rapid-on capability. Claim 6 is representative and reads as follows:

> 1. An *apparatus comprising a transceiver operable to*:
> receive, in a full power mode, a plurality of superframes, wherein the superframe comprises a plurality of *data* frames followed by a *synchronization frame*;
> receive, in the full power mode, a *synchronization signal*;
> transmit a message to enter into a *low power mode*;
> *store, in the low power mode, at least one parameter* associated with the full power mode operation *wherein the at least one parameter comprises at least one of a fine gain parameter and a bit allocation parameter*;
> receive, in the *low power mode*, a *synchronization signal*; and
> exit from the *low power* [sic] and restore the full power mode by using the at least one parameter and without needing to reinitialize the transceiver.

('404 patent, claim 6) (disputed terms italicized).

The '268 patent is also directed to a multicarrier transmission system with low power sleep mode and rapid-on capability. Claim 4 is representative and reads as follows:

> 4. A method, in a multicarrier transceiver, comprising:
> transmitting or receiving a message to enter a *low power mode*;
> entering the *low power mode*, wherein a transmitter portion of the transceiver does not transmit *data* during the *low power mode* and a receiver portion of the transceiver receives *data* during the *low power mode*; and
> *storing, during the low power mode, at least one parameter* associated with a full power mode.

('268 patent, claim 4) (disputed terms italicized).

1. "low power mode"

   a. *Plaintiff's proposed construction*: "a state of operation in which power is consumed, but the amount of power consumed is less than when operating in a state with full data transmission capabilities"

   b. *Defendants' proposed construction*: "state of operation in which available power is reduced"

c. *Court's construction*: "state of operation in which power is consumed, but the amount of power consumed is less than when operating in a state with full data transmission capabilities"

The primary dispute between the parties with respect to this term appears to center on whether low power mode requires that less power be supplied to the circuitry or whether less power is consumed by the device. The parties also disagree about whether the claimed "low power mode" includes both the "sleep mode" and "idle state/mode" described in the specification.

Neither sleep mode nor idle state/mode are mentioned in any of the claims. Defendants expended significant effort both in briefing and at oral argument to argue that "idle state" is not a low power mode. I disagree. The specification states in a number of different places that the invention could be incorporated into a computer and that it would be desirable in that situation that it could "enter a 'sleep' mode in which it consumes reduced power." ('404 patent at 6:2-3). The specification describes this as an "'idle' state . . . similar in many ways to the sleep mode state." (*Id.* at 6:19:24). Defendants argue that it is significant that the specification sometimes calls this a "state" instead of a "mode." (D.I. 158 at 21:10-22:3). I do not think so. Elsewhere in the specification, the same idle state is referred to as an "idle mode." ('404 patent at 8:63). It seems to me that sleep mode and idle state/mode are both low power modes implemented in different contexts.

The dispute over whether low power mode is achieved through lower power consumption or lower power supply is readily resolved by looking to the claim language. Low power mode appears in independent claims 1, 6, 11, and 16 of the '404 patent. Although claim 1 of the '404 patent is not asserted, "we look to the words of the claims themselves, both asserted and nonasserted, to define the scope of the patented invention." *Vitronics Corp. v. Conceptronic, Inc.*, 90 F.3d 1576, 1582 (Fed. Cir. 1996). Claims 1 and 11 read, in part, "[enter/entering] into the low

power mode by reducing a power consumption of at least one portion of a transmitter." ('404 patent, claims 1 & 11). Claims 6 and 16 do not include this phrase describing how low power mode is achieved. "Unless the patent otherwise provides, a claim term cannot be given a different meaning in the various claims of the same patent." *Georgia-Pac. Corp. v. U.S. Gypsum Co.*, 195 F.3d 1322, 1331 (Fed. Cir. 1999). Read in the context of the specification, I find no reason why the term should be given different meaning in claims 6 and 16 than it has in claims 1 and 11, which indicate that low power mode is achieved through lower consumption of power.

Finally, the parties dispute whether low power mode includes, as Defendants argue, a state in which the device is completely off. (D.I. 144 at 61). Defendants' argument on this point is inconsistent with the claims and specification. While in low power mode, the transceiver must be able to either transmit or receive a synchronization signal. ('404 patent, claims 1 and 6). The argument that some power is consumed by the transceiver even in low power mode is supported by the specification. (*Id.* at 7:44-56). For these reasons, I will adopt Plaintiff's construction.

2. "stor[e/ing], in [a/the] low power mode, at least one parameter"

   a. *Plaintiff's proposed construction*: "maintaining in memory at least one parameter associated with a mode of operation with full data transmission capabilities, while in a low power mode"

   b. *Defendants' proposed construction*: "maintain[ing] in memory throughout a/the low power mode, at least one parameter"

   c. *Court's construction*: "maintain[ing] in memory, while in low power mode, at least one parameter"

The parties first dispute whether the construction should include the limitation that the parameter must be associated with full power mode. Defendants argue that this limitation already appears in the claim language and including this in the claim construction would be superfluous. (D.I. 144 at 66). Plaintiff did not reply to this argument. I agree with Defendants. The claim

language includes this limitation already when it calls for storing "at least one parameter associated with the full power mode operation." ('404 patent, claim 6). It would be redundant to include this in the court's construction of this term.

The parties also disagree about whether the parameter must be maintained throughout the duration of the low power mode. Plaintiff argues that there is no support in the claim language for requiring a particular duration for how long the parameter is stored. (D.I. 144 at 65). Defendants counter that it is a "fundamental requirement" of the invention that the parameter be stored for the entire duration of the low power mode. (*Id.*). Reading the claim as a whole, I find it is unnecessary to include this requirement in the construction of this term. The claim specifies that the device will "exit from the low power mode and restore the full power mode by using the at least one parameter." ('404 patent, claim 6). Therefore, the rest of the claim itself implies that the parameter is stored at least until the device exits from low power mode. This is captured by the court's construction of "maintain[ing] in memory, while in low power mode, at least one parameter."

3. "wherein the at least one parameter comprises at least one of a fine gain parameter and a bit allocation parameter"

a. *Plaintiff's proposed construction*: "wherein the at least one parameter includes a fine gain parameter and/or a bit allocation parameter"

b. *Defendants' proposed construction*: "wherein the at least one parameter includes both a fine gain parameter and a bit allocation parameter"

c. *Court's construction*: "wherein the at least one parameter includes a fine gain parameter and/or a bit allocation parameter"

Plaintiff argues that its construction follows the plain language of the claim and notes that the parameters listed in the claim are not categories but rather two parameters from a list of parameters that may be stored. (D.I. 144 at 90-92). Defendants argue that the phrase "at least one of" modifies both terms, requiring that both a fine gain and a bit allocation parameter must be

stored, citing Federal Circuit case law in support of their position. (*Id.* at 91). Defendants are correct that the Federal Circuit has previously construed this same phrase to require one of each of the terms in the list as a matter of grammatical construction. *SuperGuide Corp. v. DirecTV Enterprises, Inc.*, 358 F.3d 870, 886 (Fed. Cir. 2004). As a number of district courts have recognized, however, "*SuperGuide* did not erect a universal rule of construction for all uses of 'at least one of' in all patents." *Fujifilm Corp. v. Motorola Mobility LLC*, 2015 WL 1265009, at *8 (N.D. Cal. Mar. 19, 2015).

I find that this phrase is readily construed by looking at the full context of the claim itself, without having to resort to grammatical arguments. The relevant portion of the claim reads "storing, in the low power mode, *at least one parameter* associated with the full power mode operation wherein the at least one parameter comprises at least one of a fine gain parameter and a bit allocation parameter." ('404 patent, claim 11 (emphasis added)). The phrase "at least one parameter" indicates that the patent contemplates a situation where only one parameter would be stored. Defendant's construction would require a minimum of two parameters to be stored and is, therefore, inconsistent with the plain language of the claim. For this reason, I will adopt Plaintiff's construction.

4. "fine gain parameter"

   a. *Plaintiff's proposed construction*: "a parameter used to determine power level on a per subcarrier basis"

   b. *Defendants' proposed construction*: "Indefinite"

   c. *Court's construction*: "parameter used to determine power level on a per subcarrier basis"

Defendants only argument with respect to this term is that "fine" is a word of degree and, therefore, this term is necessarily indefinite. (D.I. 144 at 68). I disagree. The claim language does

not instruct that anything be measured or adjusted, as in, "make a fine adjustment to the gain," for example. Rather, the claim instructs that a specific parameter, named the "fine gain parameter," is to be stored. Although the claim language itself does not provide specific guidance as to the meaning of this term, the specification supports Plaintiff's construction, particularly when considered in the context of the extrinsic evidence Plaintiff presents to show that a person of ordinary skill in the art would understand that "fine gain" refers to the gain on a subchannel. For example, the specification discusses the requirements of initialization, and in doing so distinguishes between "setting the channel gains" and "adjusting the fine gains on the subchannels." ('404 patent at 3:12-14). This distinction is substantially supported by the ITU-T G.992.1 Standards Plaintiff referenced in its briefing and presented at oral argument as evidence of what a person of ordinary skill in the art would understand "fine gain" to mean.[2] (D.I. 144 at 70; D.I. 190 at 121:17-122:5). Therefore, I will adopt Plaintiff's construction.

5. "bit allocation parameter"

a. *Plaintiff's proposed construction*: "parameter used to determine a number of bits to be carried by a subcarrier on a per subcarrier basis"

b. *Defendants' proposed construction*: "parameter specifying the number of bits to be carried by a subchannel"

c. *Court's construction*: "parameter used to determine a number of bits to be carried by a subcarrier on a per subcarrier basis"

The parties have two disputes in construing this term. First, they disagree on whether the parameter is used to determine the number of bits or whether it specifies the number of bits. Second, they dispute whether the parameter provides the number of bits carried by a single subcarrier or whether it provides the number of bits on a per subcarrier basis, i.e. whether the Bit

[2] The relevant time period for this understanding is January 26, 1998, the priority date of both the '404 and '268 patents.

Allocation Table referenced in the specification is itself a bit allocation parameter. As to the first dispute, limiting the term to mean "specifying" would encompass how the number of bits is determined when a Bit Allocation Table is used, as described in the exemplary embodiment. The word "determine" also encompasses the use of a table to perform this task. Defendants argue that using "determine" unduly broadens the definition. I disagree. Only if I were to limit the claim to require that the only form of a bit allocation parameter be a Bit Allocation Table would Defendants' argument carry the day. The specification describes a method for constructing the Bit Allocation Table. But it is a parameter and not the Table itself that is claimed. It is not difficult to imagine other methods of determining the number of bits to be carried that do not involve a Bit Allocation Table being the parameter that is stored. Thus, I do not limit the construction to the exemplary embodiment.

The second dispute is readily resolved by turning to the specification. The patent lists some of the requisite parameters for waking from sleep mode and "Bit Allocation Tables" is included in that list. ('404 patent at 8:6-12). It seems to me that a full Bit Allocation Table is one example of the bit allocation parameter referenced in the claims. Therefore, Defendants' argument that a bit allocation parameter is nothing more than a single entry in a Bit Allocation Table must fail. Plaintiff's position that the number of bits must be specified for each subcarrier, not just a single subcarrier, is supported by the specification and comports with the purpose of the invention, i.e., allowing a transceiver to wake from sleep mode without reinitializing. Furthermore, the claim does not limit the form of the parameter to only a Bit Allocation Table. Therefore, I will adopt Plaintiff's construction.

6. "synchronization frame"

a. *Plaintiff's proposed construction*: "a frame that indicates a superframe boundary"

b. *Defendants' proposed construction*: "frame that carries no user or overhead bit-level data and is inserted to establish superframe boundaries"

c. *Court's construction*: "frame that indicates a superframe boundary"

The parties agree that synchronization frames indicate or establish superframe boundaries. The parties disagree, however, as to whether the synchronization frame must be limited to that defined in the ITU Document G922.2. Defendants insist that it must be so limited, pointing to the specification, which references this ITU Document. ('404 patent at 5:5-12). There are two problems with Defendants' argument, however. First, the reference to the ITU document is made after the reference to data frames and is also given specifically as an example ("data frames (*e.g.*, sixty-eight frames for ADSL as specified in ITU Document G.992.2)"). No reference is made to the ITU document after the synchronization frame is mentioned. Second, this is a simply an exemplary embodiment and I find no evidence to support limiting the claim to one exemplary embodiment. Therefore, I will adopt Plaintiff's construction.

7. "synchronization signal"

a. *Plaintiff's proposed construction*: "an indication used to establish or maintain a timing relationship between transceivers"

b. *Defendants' proposed construction*: "reference wave used to establish or maintain a timing relationship between transceivers"

c. *Court's construction*: "signal used to establish or maintain a timing relationship between transceivers"

The only dispute between the parties with respect to this term is whether the signal is "an indication" or a "reference wave." Defendant argues strenuously that the signal must be a wave, arguing that all of the examples of synchronization signals given in the specification are "reference waves." (D.I. 144 at 81). Defendant does not explain, however, what exactly a reference wave is in this context. The phrase "reference wave" does not appear anywhere in the patent and

Defendant has offered no definition. I will not construe this claim term to include a phrase that adds ambiguity and uncertainty to the meaning of the term. Plaintiff's proposal of "indication," however, is little better as the word "indication" could easily be deemed to include things that are not "signals." It seems to me that "signal" is a well-understood term that has a plain meaning to those skilled in the art. I see no need to substitute a different word that would introduce ambiguity into the meaning of the term. Therefore, I will adopt Plaintiff's proposed construction, modified as follows: "signal used to establish or maintain a timing relationship between transceivers."

8. "apparatus comprising a transceiver operable to"

   a. *Plaintiff's proposed construction*: "See above for the construction of 'transceiver'; otherwise plain meaning"

   b. *Defendants' proposed construction*: "The preamble is limiting[3] and this is a means-plus-function limitation. The "transceiver" is the CPE transceiver depicted in Figure 2"

   c. *Court's construction*: "plain meaning with 'transceiver' as previously construed"

Defendants argue that this element from the preamble of several claims is limiting as a means-plus-function claim element governed by 35 U.S.C. § 112 ¶ 6 because the word transceiver does not impart definite structure. (D.I. 144 at 85). Plaintiff responds that transceiver has a well-understood structural meaning in the art. (*Id.* at 86). When the word "means" does not appear in the claim element, there is a presumption that the element is not means-plus-function. *Williamson v. Citrix Online, LLC*, 792 F.3d 1339, 1349 (Fed. Cir. 2015). "[T]he presumption can be overcome and § 112, para. 6 will apply if the challenger demonstrates that the claim term fails to 'recite sufficiently definite structure' or else recites 'function without reciting sufficient structure for performing that function.'" *Id.*

[3] Defendants argue only that the preamble provides a functional limitation. Therefore, I decline to address whether the preamble is otherwise limiting.

I conclude that § 112 ¶ 6 does not apply to this claim element. The word "means" does not appear in the claim element, so I begin with the presumption that § 112 ¶ 6 does not apply. Defendants have not overcome this presumption. Although "apparatus" is a non-structural term, the word "transceiver" imparts sufficient structure to the claim element. Transceiver is not a generic term like module or device. *Id.* at 1350. Rather, transceiver is the name of a device well known in the field of communications and, furthermore, the claimed transceiver is sufficiently described in the specification. (*See* '404 patent at 4:14-5:36). I will adopt Plaintiff's construction.

9. "data"

a. *Plaintiff's proposed construction*: "non-control information"

b. *Defendants' proposed construction*: "digital information"

c. *Court's construction*: "content"

Plaintiff initially argued that this term should be construed to have its plain meaning. (D.I. 144 at 87-88). Plaintiff proposed "non-control information" in response to Defendants' initial proposed construction, "information." (*Id.* at 89). At oral argument, Defendants proposed to narrow their construction to "digital information." (D.I. 190 at 144:21). I am not persuaded that any of these constructions provide any clarity as to the meaning of the term "data." At oral argument, I proposed construing the term to mean "content." (*Id.* at 151:21). Plaintiff agreed to this proposed construction. (*Id.* at 155:9-156:1).

Defendants, however, argue that construing data to mean "content" would impermissibly narrow the meaning of "data" in some of the claims because "user data" is used in other claims. (*Id.* at 156:4-12). According to Defendants, user data is content. This position is contradicted by the patent specification, however. The specification provides that during sleep mode, "user data provided by the CO transceiver will be benign idle data such as ATM IdleCells or HDLC Flag

octets." ('268 patent at 7:34-36). Although this information is defined to be user data by the patent itself, it is not content. Therefore, I will construe data to mean content.

C. The Diagnostic Mode Patents

The '430 patent is directed to multicarrier modulation messaging for frequency domain received idle channel noise information. Claim 1 is representative and reads as follows:

> 1. A transceiver capable of *transmitting test information over a communication channel* using multicarrier modulation comprising:
>
> a transmitter portion capable of transmitting a message, wherein the message comprises one or more data variables that represent the *test information*, wherein bits in the message are modulated onto DMT symbols using Quadrature Amplitude Modulation (QAM) with more than 1 bit per subchannel and wherein at least one data variable of the one or more data variables comprises an *array representing frequency domain received idle channel noise information.*

('430 patent, claim 1) (disputed terms italicized).

The '412 patent is directed to multicarrier modulation messaging for power level per subchannel information. Claim 1 is representative and reads as follows:

> 1. A transceiver capable of *transmitting test information over a communication channel* using multicarrier modulation comprising:
>
> a transmitter portion capable of transmitting a message, wherein the message comprises one or more data variables that represent the *test information*, wherein bits in the message are modulated onto DMT symbols using Quadrature Amplitude Modulation (QAM) with more than 1 bit per subchannel and wherein at least one data variable of the one or more data variables comprises an *array representing power level per subchannel information.*

('412 patent, claim 1) (disputed terms italicized).

1. "[transmitting/receiving] test information over a communication channel"

    a. *Plaintiff's proposed construction*: "plain meaning"

    b. *Defendants' proposed construction*: "transmitting/receiving test information to/from a central office modem"

    c. *Court's construction*: "plain meaning"

Defendants seek to import a limitation into this claim requiring that the test information be transmitted either to or from a central office modem. This limitation is unsupported by either the claims or the specification. The specification does indicate that the receiving transceiver is "typically located" at the central office, but typically does not mean always. ('412 patent at 1:53). Defendants argue that the patent is directed to the solution of a particular problem: diagnosing problems without the need to dispatch a technician to the customer's home. (D.I. 144 at 97). This may be a problem identified in the specification that is solved by this patent, but the solution to the problem is not so limited. I find no basis for importing this limitation into the claim. I agree with Plaintiff that this term should be given its plain meaning. Defendants are prohibited from arguing that the term is limited to communications over a channel that includes the central office modem.

2. "test information"

a. *Plaintiff's proposed construction*: "information relating to a measured characteristic of a communication channel"

b. *Defendants' proposed construction*: "information relating to a disturbance in the communication channel"

c. *Court's construction*: "information relating to a characteristic of a communication channel or the communications equipment operating on that channel"

The parties dispute whether the test information must be measured and whether the information must relate to a disturbance in the communications channel. I find that neither of these limitations is supported by the intrinsic evidence.

Defendants contend that the description of the invention as a whole in the specification is limiting and that test information must therefore be limited to information "relate[d] to the diagnosis and resolution of communications problems caused by a disturbance on a communications channel." (D.I. 144 at 102). Defendants' argument is unavailing. The

specification states, "The systems and methods of this invention are directed toward reliably exchanging diagnostic and test information between transceivers over a digital subscriber line in the presence of voice communications and/or other disturbances." ('430 patent at 1:44-47). Nothing in this description provides any limitation on the definition of test information. The reference to disturbances means only that the invention provides a method for the exchange of test information when there is a disturbance on the line. The specification later provides an extensive, but not exhaustive, list of what test information might include. (*Id.* at 2:24-43). Many of the items in this list are unrelated to disturbances. It would be inappropriate to limit the definition of test information when nothing in the specification indicates such a limitation.

With respect to whether the information must be measured, Plaintiff argues that a person of ordinary skill in the art would recognize that the test information as claimed must be measured. (D.I. 144 at 105). Defendants counter that the specification includes a list of categories of information that may be included as the test information and that a number of the items on the list, such as Chip Type, do not require measurement to determine. (*Id.* at 104). I agree with Defendants. Although some types of test information, as defined in the specification, must be measured, other types are simply characteristics of the communications system.

Defendants further challenge Plaintiff's construction as improperly limiting the test information to characteristics of a communications channel. (*Id.*) Defendants point out that information such as Chip Type and Vendor ID are characteristics of the modems, not of the communications channel itself. (*Id.*). I agree with Defendants. The test information defined in the specification appears to more broadly encompass information related not only to the communications channel itself, but also to the equipment used at one end of the channel. Therefore, I will adopt the following construction for test information: "information relating to a

characteristic of a communication channel or the communications equipment operating on that channel."

3. "array representing frequency domain received idle channel noise information"

   a. *Plaintiff's proposed construction*: "ordered set of values representative of noise in the frequency domain measured on respective subchannels while no input signals are being transmitted on the subchannels"

   b. *Defendants' proposed construction*: "ordered set of values representative of noise in the frequency domain that was received by a transceiver on a channel in the absence of a transmission signal"

   c. *Court's construction*: "ordered set of values representative of noise in the frequency domain that was received by a transceiver on respective subchannels in the absence of a transmission signal"

The parties have three disputes with respect to this term: whether the values must be measured; whether the values represent noise on a subchannel basis; and whether the idle channel noise corresponds to "no input signals" being transmitted or simply "the absence of a transmission signal." The first and third disputes are readily resolved. There is no indication, either in the claims or in the specification, as to how these values are obtained. Certainly the values may be measured, but I cannot find support in the intrinsic evidence to limit the construction to measured values only. Furthermore, Plaintiff's own extrinsic evidence, and the only evidence presented with respect to the meaning of "idle channel noise," indicates that Defendants propose the better construction. *See* NEWTON'S TELECOM DICTIONARY 410 (15^{th} ed. 1999) (defining idle channel noise as "[n]oise which exists in a communications channel when no signals are present"). There is no support for limiting idle channel noise to noise present in the absence of "input signals." Therefore, as to these two disputes, I adopt Defendants' proposed construction.

As to the dispute over whether the values are measured on respective subchannels, I find Defendants' arguments unavailing. Defendants are correct to point out that the applicants used the

phrase "per subchannel" explicitly in the '412 patent. ('412 patent, claim 1). However, the "array" terms of the two patents are differently worded. Thus, the absence of this phrase in the claims of the '430 patent does not necessarily render the phrase superfluous in the '412 patent. Furthermore, the fact that what is claimed is an "array" implies that more than one value is included. Therefore, I decline to adopt either party's proposed construction and instead will construe this term to mean "ordered set of values representative of noise in the frequency domain that was received by a transceiver on respective subchannels in the absence of a transmission signal."

4. "array representing power level per subchannel information"

   a. *Plaintiff's proposed construction*: "ordered set of values representative of power levels measured on respective subchannels"

   b. *Defendants' proposed construction*: "ordered set of values representative of power levels of respective subchannels"

   c. *Court's construction*: "ordered set of values representative of power levels of respective subchannels"

The parties' only dispute with respect to this term is whether the values must be measured. Plaintiff argues that without specifying that the values are measured, the term could be understood to mean that the values represent power level settings. (D.I. 144 at 115). Plaintiff further argues that the very definition of test information requires that the values be measured. (*Id.* at 116). I have already rejected the argument that all test information must be measured, however. Plaintiff cites to dependent claims specifying that the power levels are "based on a Reverb signal" and, therefore, must be measured. (*Id.*). Plaintiff further points to the specification, which provides that the power levels are "detected during the ADSL Reverb signal." (*Id.*). Defendants counter that detecting is not the same as measuring and that nothing in the claims or specification require that "the *only* way to obtain power level information is to measure it." (*Id.* at 117). Defendants

further argue that there is a presumption that a limitation present in a dependent claim is not present in the independent claim. (*Id.*).

As an initial matter, I reject Defendants' argument that detect and measure have different meanings in this context. I do, however, agree with Defendants argument that the limitation in the dependent claim should not be imported into the independent claim. Plaintiff's citations to the specification describe a preferred embodiment which, it seems to me, directly corresponds with the dependent claims. While I do not see any reason these power levels could not be measured, or that they must be obtained in any particular way, I also do not see any support for requiring that they be measured. Therefore, I will adopt Defendants' proposed construction.

5. "Reverb signal"

   a. *Plaintiff's proposed construction*: "a signal generated by modulating carriers in a multicarrier system with a known pseudo-random sequence to generate a wideband modulated signal"

   b. *Defendants' proposed construction*: "any 'REVERB' signal defined in the ITU or ANSI ADSL standards in existence as of January 8, 2001"

   c. *Court's construction*: "signal generated by modulating carriers in a multicarrier system with a known pseudo-random sequence to generate a wideband modulated signal"

The primary dispute between the parties with respect to this construction is whether, as Defendants argue, the Reverb signal is limited to that defined in the referenced standards. Defendants find support for this limitation both in the fact that the term is capitalized, which Defendants take to indicate a reference to the REVERB1 signal from the standards, as well as from the reference to the standards in the specification. (D.I. 144 at 112-13). I find Defendants' argument unconvincing. Although the term "Reverb" is capitalized in the claims, it is not spelled out in all capital letters, nor does it include the number "1" at the end. Everywhere the specific standard is mentioned in the specification, it is given as "REVERB1." ('412 patent at 3:57-4:3).

If the applicant had meant to claim the specific REVERB1 signal from the relevant standards, it seems likely he would have named that specific signal in the claim. The specification refers to the REVERB1 signal from the standards when describing an exemplary embodiment and there is no evidence in the specification of any disclaimer of other ways of generating a Reverb signal.

Plaintiff's proposed construction, on the other hand, is drawn directly from the specification. (*Id.* at 3:62-64). The applicant chose to define how the Reverb signal was to be generated. Having found no compelling reason to impose additional limitations on the meaning of this term, I will adopt Plaintiff's construction.

IV. CONCLUSION

Within five days the parties shall submit a proposed order consistent with this Memorandum Opinion suitable for submission to the jury.

ADSL Line Driver/Receiver Design Guide, Part 1

by Tim Regan

Introduction

Consumer desire for faster Internet access is driving the demand for very high data rate modems. A digital subscriber line (DSL) implementation speeds data to and from remote servers with data rates of 512Kbps to 8Mbps, much faster than current 56Kbps modem alternatives. This speed of data communication is providing the Internet with the capability to transfer information in new formats such as full-motion video, while greatly improving the timeliness of conventional information access.

One very important feature of DSL technology is that the connection is handled through a normal telephone line; therefore, no special high speed cables or fiber optic links are required and every home and office is most likely DSL ready. Another feature is that the data interface can operate simultaneously with normal voice communication over the same telephone line. This allows the modem to be connected at all times and not interfere with the use of the same line for normal incoming and outgoing phone calls or faxes.

The real "magic" of DSL technology stems from the application of digital signal processing (DSP) algorithms and data coding schemes. The implementations have built-in intelligence to accommodate the wide variations of data transmission signal conditions

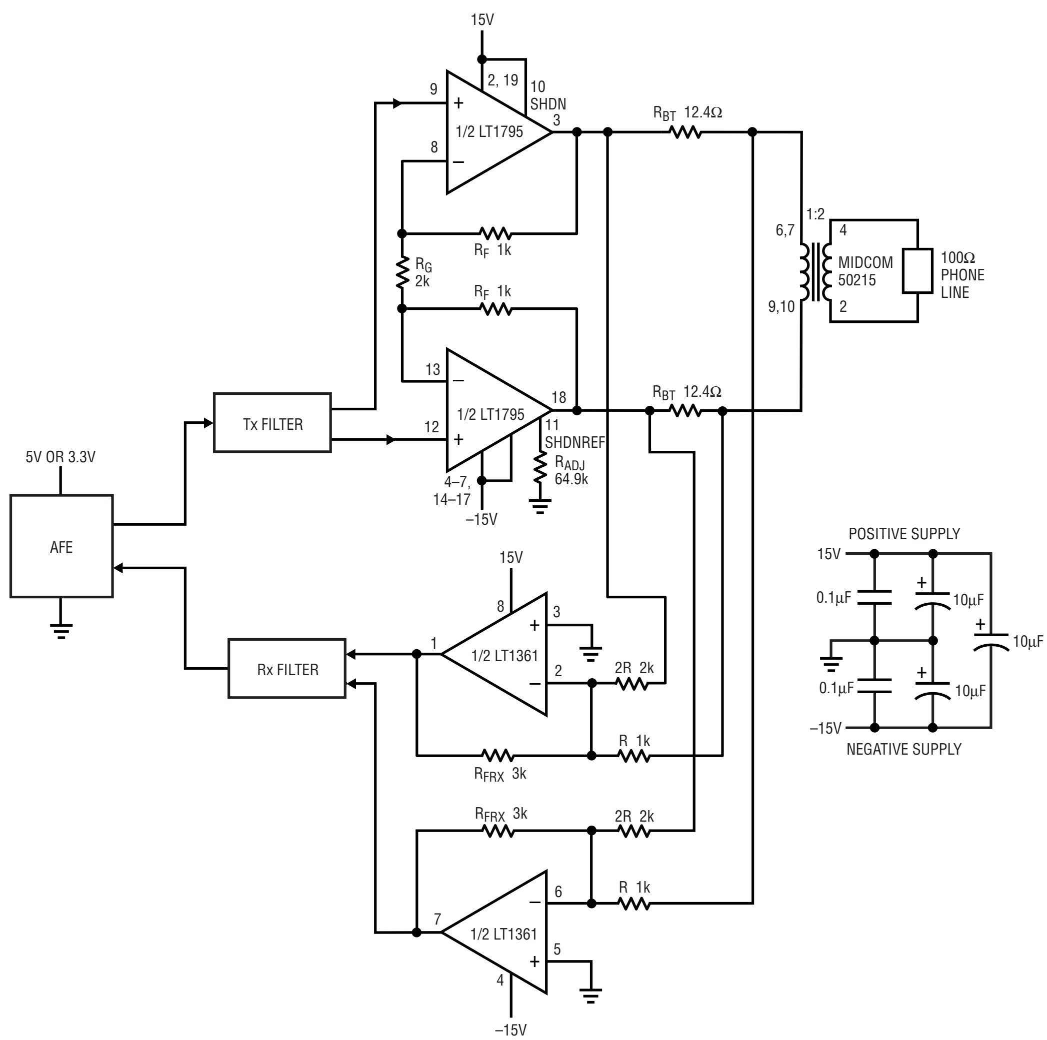
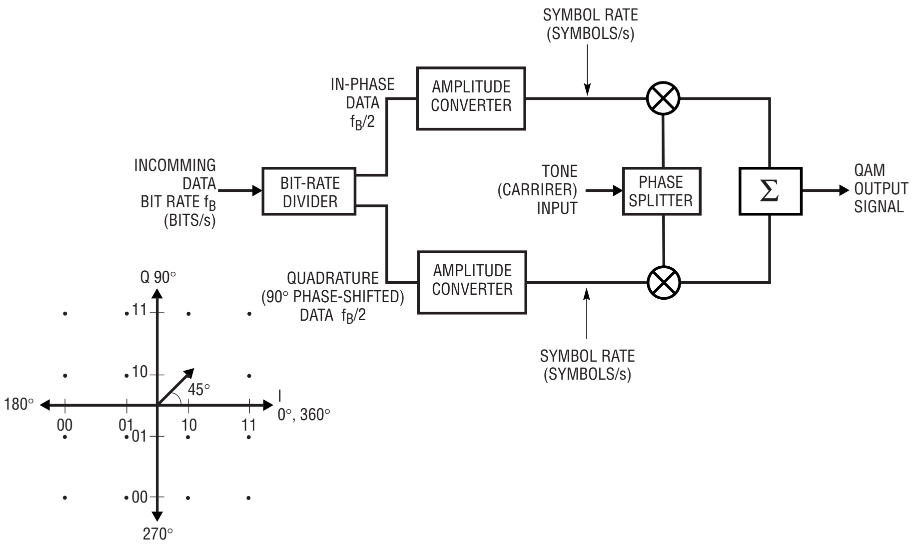


Figure 1. Central-office ADSL transceiver



CODE		LEVELS		VECTOR	
I	Q	I (2MSB)	Q (2LSB)	MAG	ANGLE (°)
00	00	–3	–3	4.2	225
00	01	–3	–1	3.2	198
00	10	–3	1	3.2	162
00	11	–3	3	4.2	135
01	00	–1	–3	3.2	252
01	01	–1	–1	1.4	225
01	10	–1	1	1.4	135
01	11	–1	3	3.2	108
10	00	1	–3	3.2	288
10	01	1	–1	1.4	315
10	10	1	1	1.4	45
10	11	1	3	3.2	72
11	00	3	–3	4.2	315
11	01	3	–1	3.2	342
11	10	3	1	3.2	18
11	11	3	3	4.2	45

Figure 2. Quadrature amplitude modulation

encountered with each connection through the telephone switching network. Sophisticated ASICs have been developed to provide small modems for PCs and handheld devices and the ability to compact many DSL lines on a single PCB card for telephone central-office deployment.

However, as is the case with almost any system, DSL still requires fundamental operational amplifier functions to put the signal on to the phone line and to pick off the small signals received at the other end. Although many system designers are competent and comfortable with DSP and all things digital, they often find their understanding of analog issues to be a bit rusty when it comes to implementing the physical connection to and from the telephone line. This series of articles will provide an overview of the requirements placed on the amplifiers and provide guidelines to component selection and the implications on distortion performance and power consumption and dissipation, the most important system issues related to the analog components.

Figure 1 shows a complete central office DSL line driver/receiver. This is the basic circuit topology that provides differential transmit signal drive to the line and detection of the differential received signal. The full requirements of DSL are easily met by using devices from Linear Technology's broad line of high speed power amplifiers for the driver and high speed, low noise dual amplifiers for the receiver. Using either current feedback or voltage feedback topologies, the family of drivers consists of amplifiers with bandwidths from 35MHz to 75MHz, slew rates in excess of 200V/µs with output current capability from 125mA to over 1 amp. The receiver family combines similar high speed performance with low noise, less than $10nV/\sqrt{Hz}$, and low quiescent operating current, less than 10mA. The devices shown in Figure 1 are the LT1795 500mA output current, 50MHz bandwidth dual op amp and the LT1361 50MHz dual amplifier with input noise voltage of $9nV/\sqrt{Hz}$ and total supply current of only 10mA.

Although there are several variations of DSL technology (SDSL, HDSL, HDSL2, VDSL and ADSL, to name a few) the requirements placed on the amplifiers for these different standards are very similar. The major difference between the approaches, as they affect the line driver, is the amount of power actually put on to the phone line by the line-driver amplifier. For simplicity, these articles will focus on the most recently approved standard, ADSL (asymmetric DSL), but the concepts discussed apply equally to any of the other standards.

This first installment will provide an overview of the requirements of ADSL and how it is done, as well as a discussion of the circuit topology and the requirements for the components used for implementation.

The Requirements for ADSL

The full specifications for ADSL are contained in two ITU (International Telecommunications Union) documents called G.992.1, for systems often referred to as Full-Rate ADSL or G.dmt, and G.992.2, a lower data rate approach often called G.Lite. Both systems use a technique called discrete multitone, or DMT, for transmitting data. With DMT, a frequency band up to 1.2MHz is split up into 256 separate tones (also call subcarriers) each spaced 4.3125kHz apart. With each tone carrying separate data, the technique operates as if 256 separate modems were running in parallel. To further increase the data transmission rate, each individual tone is quadrature amplitude modulated (QAM). As shown in Figure 2, the data to be transmitted is used to create a unique amplitude and phase-shift characteristic for each carrier tone, through the combination of I and Q data, called a symbol. The symbols represented by each tone are updated at a 4kHz rate or 4000 symbols per second. Full Rate ADSL uses up to 15 bits of data to create

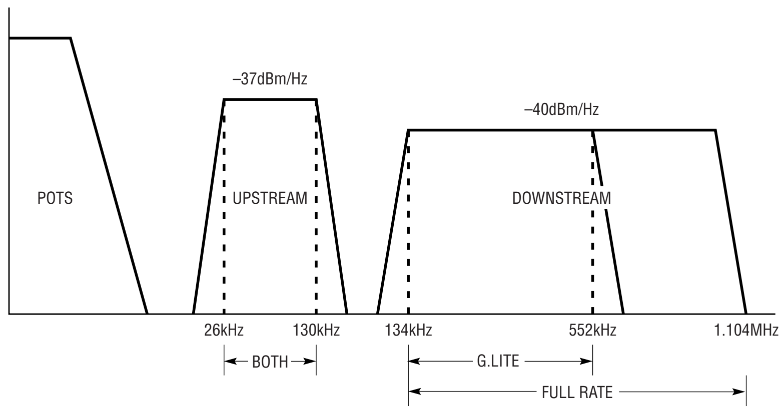


Figure 3. DMT channel allocation

each symbol. This results in a theoretical maximum of 60Kb/s for each tone. If all 256 tones are used in parallel, the total theoretical data rate can be as fast as 15.36Mb/s. For G.Lite, only 8 bits are used per symbol with only half of the carrier tones used for a theoretical maximum data rate of 4.096Mb/s.

In an actual DSL application, the tones are allocated for use depending on the direction of communication, as shown in Figure 3. Most of the tones are used for communication from the central office (CO) to an end user's PC modem (often referred to as the CPE or customer premises equipment). This direction of communication is called "downstream." The direction of communication from a PC modem to the central office (and, ultimately, to an Internet server) is called "upstream." The use of more tones for the downstream direction makes sense from an Internet-access point of view, because most users download more information than they upload. Most upstream communication with a server is simply to request information to be sent quickly downstream. This difference in data rates up- and downstream is the reason ADSL is called asymmetric DSL.

Also indicated in Figure 3 is the power spectral density (PSD) of all of the tones used. This determines the amount of signal power that needs to be put on to the phone line. The power levels are restricted to minimize crosstalk and interference into other phone lines contained in wire bundles *en route* to and from the central office. The total power required can be determined from the following equation:

$$\text{LINE POWER (dBm)} = \text{PSD (dBm/Hz)} + 10 \bullet \text{Log}(F_{MAX} - F_{MIN})$$

The downstream power requirements are much higher than the upstream requirements because of the wider bandwidth used for the transmission. For this reason, Full Rate ADSL requires more line power than G.Lite for downstream transmissions. Upstream power is the same for both Full Rate and G.Lite

Table 1. ADSL requirements

Parameter		Full Rate ADSL Downstream	ADSL G.Lite Downstream	Full Rate ADSL or G.Lite Upstream
Characteristics	Channels Used	31 to 256	31 to 128	6 to 30
	Frequency Band (kHz)	133.7 to 1104	133.7 to 552	25.8 to 129.4
	Bandwidth (kHz)	970.3	418.3	103.5
	Power Spectral Density, PSD (dBm/Hz)	–40	–40	–37
	Line Power (dBm)	20	16.3	13
Electrical Requirements	RMS Line Power (mW)	100	43	20
	Line Impedance (Ω)	100	100	100
	RMS Line Voltage (V)	3.1	2	1.4
	RMS Line Current (mA)	31	21	15
	Peak-to-Average Ratio, PAR	5.3	5.3	5.3
	Peak Line Voltage (V)	16.5	11	7.6
	Peak-to-Peak Line Voltage (V)	33	22	15.2
	Peak Line Current (mA)	170	110	76
	Peak Line Power (mW)	2725	1175	580
Theoretical Data Rates	Bits/Symbol	15	8	15 (Full) 8 (G.Lite)
	Bits/Channel (KBits/s)	60	32	60 (Full) 32 (G.Lite)
	Max Data Rate for Channels Used	13.5Mb/s	3.1Mb/s	1.4Mb/s (Full) 768Kb/s (G.Lite)

implementations. As will be seen, the line power requirement is the most significant factor in designing a line driver for a particular application.

Table 1 is a summary of the characteristics, electrical requirements and maximum data rates for ADSL modems.

The following are important items to note:

The phone line characteristic impedance for ADSL is 100Ω. This is used to determine the voltage and current required to provide the proper line-power level.

The term PAR stands for peak-to-average ratio. This term is similar to the more common term of crest factor. This determines the peak value of the voltage put on the line over time with respect to the RMS voltage level:

$$V_{PEAK} = PAR \bullet V_{RMS}$$

The DMT signal placed on the line looks basically like white noise, because many different frequencies of rapidly changing amplitude and phase are combined simultaneously. The changes of each tone are considered random as they result from an arbitrary sequence of data bits comprising the transmitted information. Over time, the signals can align and stack up to create a large peak signal. If this large peak is not processed cleanly (for example, if the line-driver amplifier clips) data errors can occur, which must be detected and resent. Transmission errors, particularly over a noisy environment such as phone lines, are inevitable. These errors are identified by a term called the bit-error rate (BER); an acceptable level to maintain fast and accurate data transmission is one error per every 10^7 symbols. The PAR is determined by the probability of the random line signal reaching a certain peak voltage during the time interval required for 10^7 symbols. For the DMT signal, this peak value is 5.3 times the RMS signal level. This factor is very important in determining both the minimum supply voltage required to prevent clipping of the signal and also the peak output current capability of the line driver.

Although the data rates shown in Table 1 are impressively fast, they are, indeed, theoretical. In an actual connection over the phone line, all manner of interference sources will alter the frequency response over the 1.2MHz band. These interference sources can contaminate or attenuate many of the carrier tones to render them completely unusable, or useful but with less than the maximum possible number of data bits encoded. Additionally, higher frequency tones are attenuated more than the lower ones, particularly over longer lengths of phone line used to make the connection.

Another issue that can render particular tones unusable or create transmission errors is distortion from the amplifier driving the line. Distortion products, whether harmonic, intermodulation or from signal clipping, from any of the carrier tones, create signal energy in the frequency spaces used by other tones. This energy also contaminates the data content of the tones and can result in fewer tones being used for data transmission. If many tones are unusable or their data handling capability is reduced, the actual data rate for any given connection can be significantly less than the theoretical maximum.

One of the best features of a DSL modem is the intelligence built in to obtain the fastest data rate for any set of line conditions. When a connection between a modem and the telephone central office is initiated, the first action to occur is called "training-up." During this interval, both ends transmit maximum power in each channel in an effort to determine which channels are best suited for use. The DSP algorithms will automatically pack the most data into the best transmission channels to maximize the data rate for a particular connection. Figure 4 illustrates a typical line spectrum during a training-up interval in a G.Lite example, as measured at the central office end.

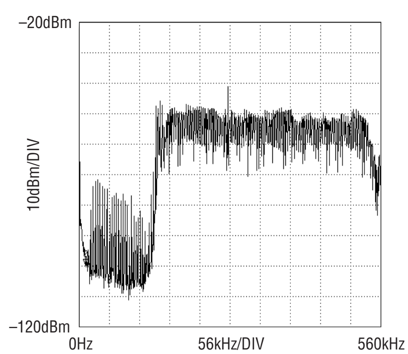


Figure 4. G.Lite training-up spectrum

A Typical ADSL Line Driver/ Receiver Circuit

Referring to Figure 1, the components shown will implement a Full Rate ADSL central office (downstream) port. A discussion of the circuit topology and aspects important for component selection follow.

Transformer Coupling

A transformer is used to connect the transceiver to the phone line, mainly to provide isolation from the line. The turns ratio of the transformer can be used to provide gain to the transmitted signal. This turns ratio has a major effect on the power supply voltages for the line-driver amplifiers. By stepping up the signal from the driver to the line via the transformer, the amount of voltage swing needed by the amplifiers is reduced. As an ideal transformer has equal power in the primary and secondary, while the voltage is stepped up, the current is stepped down. The consequences of using a step-up transformer are beneficial in that lower, more conventional supply voltages can be used, but the amplifiers must have higher current driving capability.

The limit on the turns ratio is primarily a function of the sensitivity of the receive circuitry. Step-up transformers will, unfortunately, step-down the signal received from the phone line. Further attenuation of the received signal by the transformer in addition to the inherent transmission line attenuation can cause the receiver to stop functioning. If this occurs, the modem will disconnect from the line.

A transformer should be selected for a flat, distortion-free frequency response from 20kHz to 2MHz to cover the full frequency spectrum for an

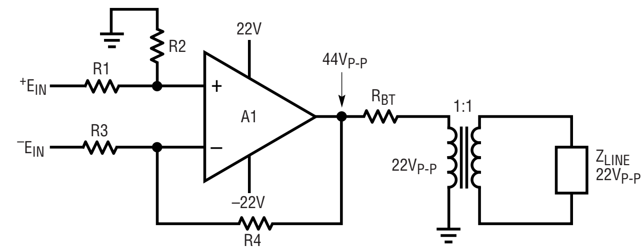


Figure 5a. A single-ended driver requires a high supply voltage to produce the desired peak-to-peak swing of the DMT signal on the phone line.

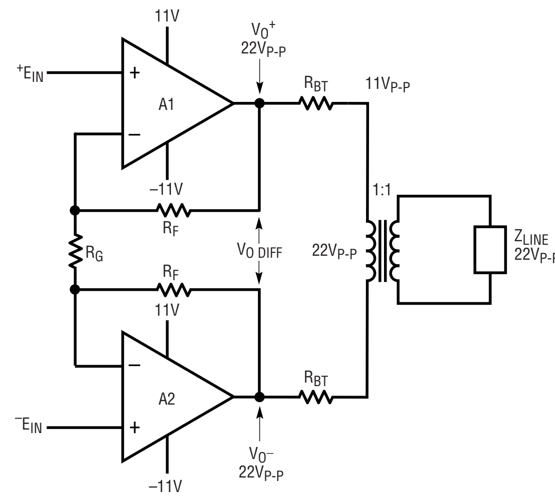


Figure 5b. A differential driver achieves the same swing with half the supply voltage of the single-ended driver.

ADSL transmission. Minimal insertion loss in the transformer over the same frequency range is also desirable. Insertion loss, usually specified in dBm, is power lost in the transformer. The driver amplifier must provide this additional power in order to maintain the required signal power level on the phone line.

Transformer Termination Resistors

The two resistors (called back-termination resistors) shown between the amplifier outputs and the primary of the transformer are inserted for two reasons: to provide a means for detecting the received signal and to make the impedance of the modem match the impedance of the phone line. The receiver circuit is two difference amplifiers that provide gain to the small signals that appear across the termination resistors. The connection and scaling of the input resistors to the receiver amplifiers are purposely set to provide a first-order cancellation of the simultaneously occurring transmit signal. This technique is called "echo cancellation" and the circuit topology is called a "2-wire to 4-wire hybrid" (the 2-wire phone line interfaces with four wires, the two differential driver lines and the two receive signal lines). The cancellation of the transmitted signal from the received signal path is not perfect. Due to signal phase shifts and resistor mismatching, a factor of 6dB to 20dB of attenuation is typical, with higher frequencies being cancelled less. The amount of transmitted signal that remains is cancelled digitally by DSP echo-canceling algorithms.

The value of the termination resistors is a function of the line impedance and the transformer turns ratio. The turns ratio, n, is defined by the number of turns of the winding connected to the phone line (the secondary) divided by the number of turns of the driver side winding (the primary). To make the modem impedance match the line impedance, the total impedance across the primary winding is determined by the following relationship:

$$R_{PRIMARY} = \frac{Z_{LINE}}{n^2}$$

To provide balanced drive to the primary of the transformer, so that each power amplifier shares the work load evenly, each termination resistor is set to a value of one-half of $R_{PRIMARY}$.

This value of termination resistance on the primary is also optimal for receiving maximum power from the line. The received signal on the phone line, e_{RX}, driving the secondary through the line impedance, Z_{LINE} (nominally 100Ω) will develop signal power in the primary per the following relationship:

$$\text{RECEIVED PRIMARY POWER} = \frac{e_{RX}^2}{\dfrac{Z_{LINE}^2}{n^2 \bullet R_{PRIMARY}} + 2 \bullet Z_{LINE} + n^2 \bullet R_{PRIMARY}}$$

which is also at a maximum when

$$R_{PRIMARY} = \frac{Z_{LINE}}{n^2}$$

While the termination resistors serve an important purpose, they also create significant signal and power loss. With the resistors set to their proper value, one-half of the power delivered by the amplifiers is dissipated in these resistors. To deliver 100mW of signal power to the phone line, for example, requires the driver amplifiers to output at least 200mW of power.

Why Differential Drive?

Two amplifiers configured as a differential gain stage are typically used to provide signal drive to the primary of the transformer. There are two reasons for this configuration: it reduces the supply voltage to the amplifiers by a factor of two and also cancels any even harmonic distortion nonlinearity contributed by the amplifiers.

With single-ended drive of the primary, the supply voltage for the amplifier must be large enough to provide the full peak-to-peak signal swing of the DMT signal placed on to the phone line. With differential drive, each amplifier contributes just one-half of the peak signal amplitude; therefore, the total supply voltage is only one half the peak-to-peak voltage level placed on the line. This is shown conceptually in Figure 5. This reduction in supply voltage allows the use of the standard power supply voltages available in computers for the high speed DSL modem card.

A differential amplifier will ideally cancel all even harmonic distortion products. This is due to the application of a signal that is the difference between two signals, one signal being

an inverted version of the other, to the primary of the transformer. This can be shown mathematically by representing the linear output signals of the amplifiers as a power series:

Each output is a linear function of the input signal:

$V_O = f(E_{IN})$

which, represented as a power series, is

$V_O = a_1E_{IN} + a_2E_{IN}^2 + a_3E_{IN}^3 + a_4E_{IN}^4 + a_5E_{IN}^5 \ldots$

The inputs to the differential amplifier are E_{IN}^+ and E_{IN}^-; therefore:

$V_O(+) = a_1E_{IN} + a_2E_{IN}^2 + a_3E_{IN}^3 + a_4E_{IN}^4 + a_5E_{IN}^5 \ldots$

and

$V_O(-) = -a_1E_{IN} + a_2E_{IN}^2 - a_3E_{IN}^3 + a_4E_{IN}^4 - a_5E_{IN}^5 \ldots$

The differential output of the amplifier stage is

$V_{ODIFF} = V_O(+) - V_O(-)$

therefore:

$V_{ODIFF} = 2a_1E_{IN} + 2a_3E_{IN}^3 + 2a_5E_{IN}^5 + \ldots$

which does not contain any even harmonic products. The complete cancellation of even harmonics depends on the gain and phase-shift matching of the amplifiers and the signal paths over the frequency range of concern.

Bandwidth, Slew Rate and Noise Requirements of the Amplifiers

High speed amplifiers with bandwidths much wider than the transmitted signal bandwidth should be used to maintain flat gain and constant phase shift of the DMT signals. The amount of gain required in the transmit power amplifiers is dependant on the signal levels provided by the analog front end (AFE), which is a circuit block that provides the interface between the line transceiver and the DSP processor. The gain must be sufficient to put the proper amount of power on the phone line for the DSL standard being implemented (refer to Table 1). The maximum frequency to be processed by the amplifiers is also a function of the standard being applied; this, in turn, sets the minimum bandwidth required. As a rule of thumb, the gain bandwidth product specification of the amplifiers used should be at least five times the required value to maintain linear accuracy over the transmitted signal spectrum. This specification provides an indication of the distortion-free, high speed signal processing capability of the amplifier. For example, a Full Rate ADSL downstream transmitter with a gain of four and a maximum frequency of 1.1MHz requires a gain-bandwidth of 4.4MHz; therefore, amplifiers should be chosen that have a gain-bandwidth specification of at least 22MHz. Parts with higher bandwidths are even better for preserving excellent gain and phase shift matching over the 1.1MHz band of operation.

The slew rate of the amplifiers used is not so critical, because the signal spectrum is typically band-limited by filter networks. The step response of these filters slows down the rise and fall times of the signals presented to the amplifiers. A slew rate of at least 10V/µs is usually adequate. However, very fast slew rates are essentially free in wideband amplifier designs. Internal biasing currents charging and discharging internal compensation capacitors and individual node capacitances of the circuit determine the slew rate of an amplifier. To produce a high frequency amplifier, circuit-biasing currents are increased to minimize impedances at critical circuit nodes and small geometry transistor structures are used to minimize stray capacitance. This results in very fast slew rates for the amplifier as an inherent byproduct of a high gain-bandwidth product characteristic. Faster slew rates ensure very fast dynamic response and reduced signal distortion.

Low noise characteristics, together with a wide gain bandwidth capability are most important for the amplifiers used in the receive circuitry. On a typical connection, a phone line will have a noise floor

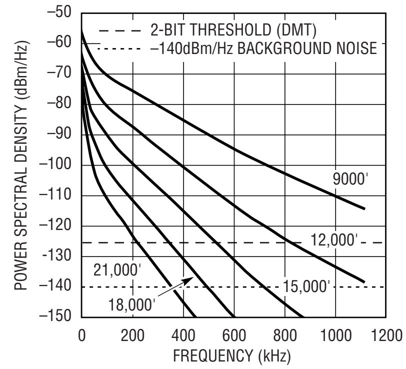


Figure 6. Typical received signal power spectral density, AWG26 loops

power spectral density of –140dBm/Hz. This is equivalent to a noise voltage of $31nV/\sqrt{Hz}$. The receiver amplifier should have a noise spectral density in the band between 20kHz and 1MHz lower than this level. Linear Technology provides several fast amplifiers with noise voltage spectra of less than $10nV/\sqrt{Hz}$. Lower noise is required in inverse proportion to the turns ratio of the transformer used to address the attendant reduction in both the noise floor and the received signal.

The amount of signal received is a function of the length of phone line used to make the connection, as shown in Figure 6. This is referred to as the loop length. Very long loop lengths can severely attenuate the transmitted signal, particularly at the higher channel frequencies. The greater the attenuation of a channel, the fewer data bits can be transmitted in that channel, which affects the overall communication data rate. As a rule of thumb, a received signal-to-noise ratio of 18dB allows two data bits to be used in a channel. With each 3dB of additional signal above the noise floor, an extra bit of data can be used. With 45dB to 50dB signal-to-noise ratio, a full 12 bits of data can be exchanged in one channel frequency.

The next installment in this series will provide the design calculations to determine the minimum requirements for supply voltage, current drive capability and resultant power consumption and dissipation. In addition, heat management issues will be discussed.

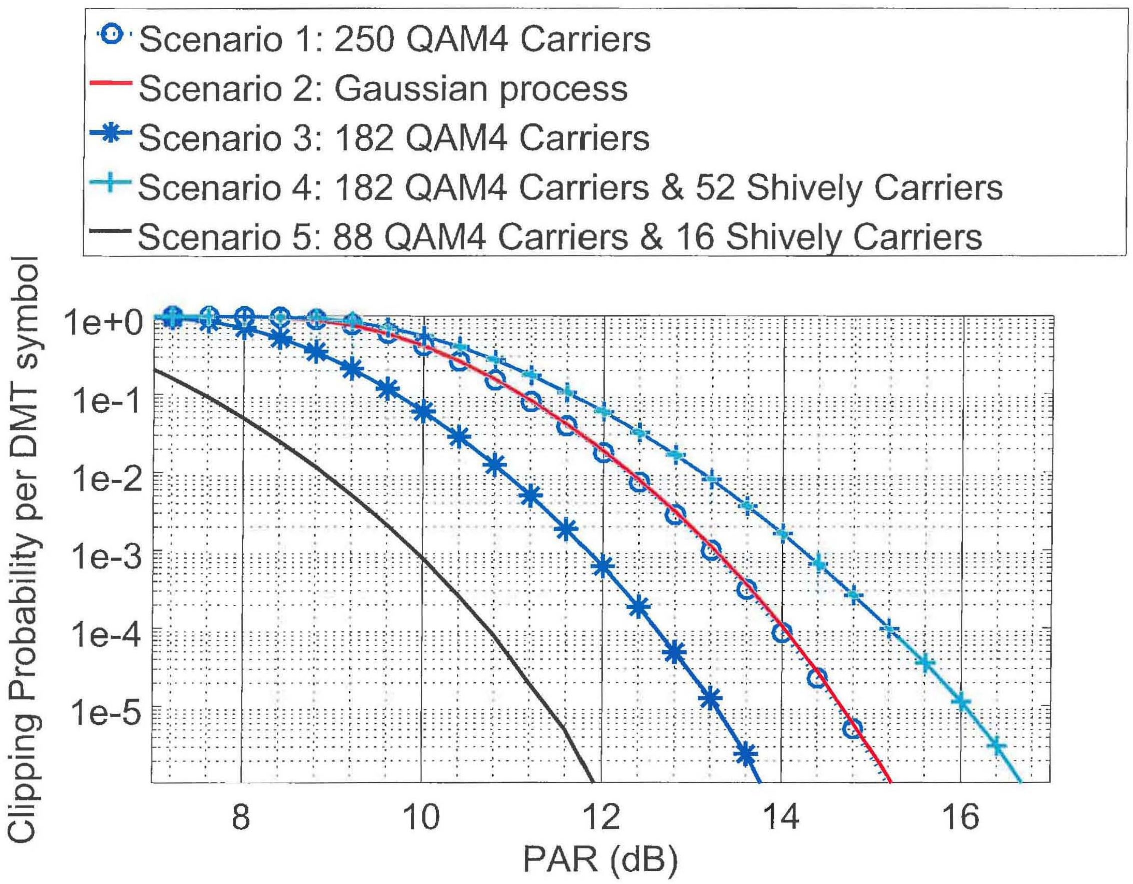
tellado18k.m **Sat Jun 17 07:56:10 2017** **1**

```
clear all
format compact
M  = 4;          %repetitions per bit
N  = 256;        %max number of tones or subcarriers
Zl = 6;          %number of low freq zero tones
Zs = 4*M;        %number of Shively tones
ZH = 146;          %number of unused high freq tones
P  = round(Zs/M) %number of repeating bits
K  = 3*10^7      %number of DMT symbols to simulate. 1e-6 is 3min, 1e-7 is 30min

PAR  = zeros(1,K);
PARz = zeros(1,K); %Zero tones
PARs = zeros(1,K); %Shively
PARg = zeros(1,K);
tic
for k=1:K
  if mod(k,10^6)==0
    k
    toc
    tic
    fflush(stdout);
  end
  bits = sign(randn(1,P));
  repeat_bits = kron(bits,ones(1,M));
  X = .707*(sign(randn(1,N-Zl)) + j*sign(randn(1,N-Zl))); %random 4QAM symbols
  X(64-Zl) = 1; %model constant pilot
  Xz = X;
  Xz(end-Zs-ZH+1:end)=0;
  Xs = Xz;
  Xs(end-Zs-ZH+1:end-ZH)=repeat_bits;
  Y = [zeros(1,Zl), X, 0, fliplr(conj(X )), zeros(1,Zl-1)];
  Yz = [zeros(1,Zl), Xz, 0, fliplr(conj(Xz)), zeros(1,Zl-1)];
  Ys = [zeros(1,Zl), Xs, 0, fliplr(conj(Xs)), zeros(1,Zl-1)];
  y = ifft(Y);
  yz = ifft(Yz);
  ys = ifft(Ys);
  Ave = (y*y')/length(y);
  Peak = max(y.*y);
  Peakz = max(yz.*yz);
  Peaks = max(ys.*ys);
  PAR(k) = 10*log10(Peak);   %PAR for 4QAM IFFT output
  PARz(k) = 10*log10(Peakz); %PAR for 4QAM IFFT output with zero tones
  PARs(k) = 10*log10(Peaks); %PAR for 4QAM IFFT output with Shively tones
  PARg(k) = 10*log10(max(randn(1,2*N).^2)); %PAR of a Gaussian symbol with 2*N points
end
PAR  = real(PAR + 10*log10(2*N)); %normalize to correct for Matlab IFFT power loss of 2N
PARz = real(PARz + 10*log10(2*N));
PARs = real(PARs + 10*log10(2*N));
PARg = real(PARg + 10*log10((N-Zl)/N)); %normalize Guassian power to N-Zl tones out of N
Axis = 6:0.4:20;
Np = hist(PAR,Axis);
Ng = hist(PARg,Axis);
Nz = hist(PARz,Axis);
Ns = hist(PARs,Axis);

figure(2)
semilogy(Axis,1-cumsum(Np)/K,':o','LineWidth',2,'MarkerSize',9, ...
         Axis,1-cumsum(Ng)/K,'r-','LineWidth',2,'MarkerSize',10,Axis,1-cumsum(Nz)/K,'b-*', ...
         'MarkerSize',12,'LineWidth',2,Axis,1-cumsum(Ns)/K,'-+', ...
         'LineWidth',2,'MarkerSize',10)
set(gca,'fontsize',18)
xlabel('PAR (dB)','fontsize',18)
ylabel('Clipping Probability per DMT symbol','fontsize',18)
```

EXHIBIT
tabbies
Tellado
2010
6/20/17

TQ Delta Exhibit 2010
Cisco Systems, Inc. v. TQ Delta LLC
IPR2016-01020

```
leg = legend('Scenario 1: 250 QAM4 Carriers','Scenario 2: Gaussian process',
            'Scenario 3: 182 QAM4 Carriers',
            'Scenario 4: 182 QAM4 Carriers & 52 Shively Carriers')
set(leg,'fontsize',18)
grid on,shg
axis([7 17 32/K 1])
```



TQ Delta Exhibit 2011
Cisco Systems, Inc. v. TQ Delta LLC
IPR2016-01020

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A. Yes.
Q. Okay. And you referenced Figure 6 on page 18 of your declaration as being one of the considerations you used to select 182 random carriers and 52 Shively carriers; right?
A. Ask the question again.
Q. You reference Figure 6 on page 18 of your declaration as one of the bases for your selection of 182 random carriers and 52 Shively carriers; correct?
A. I was looking to model a loop for which the relationship between attenuation and crosstalk was such that Shively is impactful, interesting, useful. And there is many combinations of crosstalk in attenuation I could have selected. I wanted to find some parameters that showed the benefits of Shively and, at the same time, show the weakness of Shively.
And I picked one example from Figure 6 to justify the selection of parameters, but I could have selected many other combinations of attenuation and crosstalk that also included by my simulation.
Q. Okay. So you said -- what you just said is, "I could have selected many other combinations of attenuation and crosstalk that included" -- strike that.

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You said, "I could have selected many other combinations."
A. So I'm modeling a relationship between random carriers and structured carriers, and there is many combinations of attenuation and crosstalk that justify those selections.
Q. Okay.
A. And Figure 6 includes a cable that justifies that selection.
Q. But you didn't point to any of the other examples that justify that selection, did you?
A. I give examples of crosstalk, which I could have used to justify those selections. I didn't specifically point out to any combination of crosstalk and loss that will justify those, outside that one.
I only justified my simulation based on one, but it applies to many other cases.
Q. So the noise profiles that you referenced in your paragraphs 9 through 13, you didn't actually use those in selecting your Shively carriers, did you?
A. Repeat the question.
Q. The noise profiles that you reference in your paragraphs 9 through 13, you didn't actually

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apply those in selecting your 182 random carriers and 52 Shively carriers, did you?
A. ADSL transceivers have to work over many combinations of loops, gauges, crosstalk attenuation. I didn't go through all the combinations. I just picked one combination to justify my simulation.
I only need to find one example to justify a simulation. There is many other combinations.
Q. And do you believe that the one 12,000-foot attenuation curve that you picked justifies your selection of those carriers?
A. So my simulation shows that 182 QAM random carriers, 52 structured carriers has high PAR implementing Shively's techniques.
To come up with 182 and the 52, I need to justify where I get the 182 and 52, and I could have done it through combinations of loss and crosstalks. There is infinite number of combination. I pick one to justify it, and then it applies more generally.
Q. Okay. The one you picked, though, the 12,000-foot loop, and not taking into consideration any noise other than the noise floor, that's not the one that Dr. Short used; correct?
MR. McDOLE: Objection to form.

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THE WITNESS: Can you repeat the question?
BY MR. McANDREWS:
Q. The one that you picked, which is a 12,000-foot loop, not taking into consideration any noise other than the noise floor, that's not the one that Dr. Short used; correct?
MR. McDOLE: Objection; form.
THE WITNESS: Ask the question again.
BY MR. McANDREWS:
Q. The one that you picked, which is a 12,000-foot loop attenuation curve and not taking into consideration any noise other than the noise floor, that's not the one that Dr. Short used; right?
MR. McDOLE: Objection; form.
THE WITNESS: I don't agree with the question. I want it rephrased.
BY MR. McANDREWS:
Q. Do you know which attenuation and noise characteristics Dr. Short relied on in choosing his random and Shively carriers and unusable carriers?
A. Yes. Please repeat that question.
Q. Do you know which attenuation and noise characteristics Dr. Short relied on in choosing his random, Shively and unusable carriers?

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A. I believe Dr. Short used Figure 6 or variants of it, and he selected one of these high-attenuation loops, and I believe he used the thin-gauge, high-loss AWG26 that's marked 18,000 in this figure.
Q. Okay. Did you run a simulation taking that same attenuation characteristic and noise characteristic into consideration?
A. Repeat the question.
Q. Did you run a simulation --
A. Yes.
Q. -- using an 18,000-foot loop with the attenuation characteristics shown in Figure 6 on page 18 of your declaration?
A. So in this AWG26 loop of 18,000 feet, I did a quick estimate.
Q. But you didn't run a full simulation on it?
A. Not a full simulation.
Q. And what did you determine from your quick estimate?
A. Repeat the question.
Q. What did you determine from your quick estimate?
A. That Dr. Short's approximation of a Gaussian approximation was poor. It was worse

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than -- than Dr. Short said.
Q. How much worse?
A. I don't recall. It was significantly worse.
Q. You don't recall.
Did you run a simulation?
A. I said I ran a quick estimate to see if the Gaussian approximation was good, and it was not.
Q. How did you do that quick estimation?
A. Using similar techniques to the ones that I provided.
Q. Where is that simulation?
A. So when I started working the declaration, I just did a quick estimate to see if the Gaussian approximation was correct, and I determined it was not.
Q. Did you use MATLAB for that?
A. Yes.
Q. Where are the results of that MATLAB?
A. I don't have them.
Q. Why don't you have them?
A. I just did a quick test, and then I just moved on.
Q. You didn't record the results of that MATLAB simulation?

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A. No.
Q. Did you keep the script that you used?
A. I don't recall. I keep changing the code and adding things, and I don't know if I have that version. I don't have revision control on that code.
Q. You said you don't have version control on that --
A. I don't have a revision control. The one you have is the last version.
Q. So what do you do? You just copied over the one that you used to estimate Dr. Short's version of this?
A. Repeat the question.
Q. Did you just copy over the one that was used for this quick simulation?
A. I keep modifying the code to add more things to it, and that's the latest incarnation of the code.
Q. Okay. So what happened to the version that you used to simulate the 18,000-foot loop?
A. When you write code, you could change it and save it over the same file. It gets overwritten. I mean, it gets written on top of the old version.

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Q. And did you run the simulation long enough to get a result?
A. It was quick enough to see that the Gaussian approximation that Dr. Short had was not good.
Q. How did you see that?
A. Because you see the Gaussian approximation estimate, because I'm simulating Gaussian, and I see what's happening to the Short example, and it was diverging.
Q. Explain that to me. How do you see that it's diverging?
A. Can you see graph 2? You see the solid red line?
Q. Yes.
A. That is the Gaussian process. You see Scenario 1 with 250 QAM-4 carriers? Doesn't it look very similar to the Gaussian process, the round, blue circles?
Q. Yes.
A. So I call this following a Gaussian process.
What about the cyan Scenario 4 curve? Does it -- is it tight with the Gaussian process Scenario 2 curve? It's diverging. It's worse than. The

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Gaussian process has a lower PAR than Scenario 4. It's not a good model.
This shows you a Scenario 4 that has Shively carriers cannot be modeled accurately with a Gaussian process in Scenario 2.
Q. Are you suggesting that Dr. Short's -- if you had run a full simulation on Dr. Short's 18,000-foot loop, assuming the 88 usable carriers and 16 Shively carriers and the remainder unusable, are you telling me that that would be worse than your Scenario 1 here?
A. I didn't say that. I just said it was diverging relative to a Gaussian process.
Q. A Gaussian process assuming what?
MR. McDOLE: Objection; form.
BY MR. McANDREWS:
Q. Is this the Gaussian process you assumed?
A. So Dr. Short's --
MR. McDOLE: Objection; form.
THE WITNESS: Please ask the question again.
BY MR. McANDREWS:
Q. You said it was diverging from something.
What did you use for your Gaussian process curve that you were watching it diverge from?

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A. Are you going to ask me the same question you asked before, or are you going to change the question? You changed the question at least once or twice along the way.
Q. Earlier, you said you observed this quick simulation diverging from something.
Did you say that earlier?
A. Dr. Short makes the statement that you could approximate -- I forget his exact number of carriers and Shively carriers -- and he said that you could approximate it with the Gaussian process.
You asked me if I checked that case. And I said I checked it, and it showed it was not a good approximation.
Q. And how did you do that?
A. I generated -- MATLAB has a function that generates Gaussian process, and then I checked the output of a Shively transmitter with Short's parameters, and it wasn't close to a Gaussian process. It was worse than a Gaussian process.
Q. How many carriers did you assume for the Gaussian process in this quick simulation?
A. Whatever Short had in his -- in his declaration.
Q. So it's 88 --

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A. Okay.
Q. -- random carriers --
A. Okay.
Q. -- I think you called them.
A. Mm-hmm.
Q. Or we've called them usable carriers.
Do you agree with that?
A. Okay.
Q. And 16, what we've been calling Shively carriers.
Do you understand that?
A. Say that again.
Q. We've been calling them Shively carriers, right?
A. Yeah, Shively carriers.
Q. And we've also referenced them as impaired carriers?
A. There is a little bit of a difference between those two, but keep going.
Q. And then there is unusable carriers?
A. Yes. Dr. Short's naming convention, yes.
Q. Okay. And you adopted that naming convention; right?
A. Yes.
Q. Okay. So did you run a Gaussian process

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for 88 plus 16?
A. I ran -- I compared a Gaussian process versus the 88 plus 16 Shively.
Q. So you ran a Gaussian process for 104 carriers?
A. Yes, mm-hmm.
Q. And so --
A. 88 plus 16 is not equal to 104 Gaussian.
Q. And you said you observed that?
A. I ran a similar layer. I could see they were diverging, and I just said, "Okay. It's not a good approximation."
Q. What do you mean by "they were diverging"? This is something where you cut off the simulation midstream?
A. No. When you do a simulation, you could run it to -- you could run a billion points, a gazillion points. Depending on the number of points, the differences typically increase.
Q. How many points did you run?
A. I don't recall. I have graph 2. You can just get a sense for how many DMT symbols were run for this simulation. But I don't recall how many I ran for that.
Q. If we were to -- if we were to plot that

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simulation -- this quick simulation you did, if we were to plot it on the same graph that you have on page 30 --
First of all, where would the Gaussian for the 106 carriers -- where would that be on this graph?
MR. McDOLE: Objection; form.
THE WITNESS: Ask the question again.
BY MR. McANDREWS:
Q. If we were to run a Gaussian on the 104 carriers that you ran this quick simulation on, where would that line show up in graph 2 on your -- page 30 of your declaration?
A. The Gaussian process?
Q. Mm-hmm.
A. The Gaussian process would be proportional to the power of 104 carriers.
Q. Okay. So would it be to the left of the Gaussian process for the 250 carriers that you used for --
A. Yes.
Q. -- graph 2?
A. Uh-huh. Yes.
Q. And the simulation -- so using your simulation and your MATLAB script on 88 random

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carriers and 16 Shively carriers, where would that show up on graph 2 on page 30 of your declaration?
A. The Gaussian approximation or the actual simulation?
Q. The actual simulation.
A. The actual simulation, I don't remember where it crossed over.
Q. Well, would it be to the left of the Scenario 1 line that you show here in graph 2?
A. I don't recall.
It also is a function of how many points you run. For example, if you look at the blue Scenario 3 and the red Scenario 2, they look parallel. They are parallel because they are both Gaussian-like processes. But the cyan, Scenario 4, doesn't have the same slope. It's diverging. The gap is increasing as you go to lower and lower probabilities of clipping. They are not parallel.
So when you have a Gaussian process, it drops like the red line; if you have a non-Gaussian process, it could have a different slope. And it could look better at very high clipping rates, but it could be worse at low clipping rates.
So I don't remember exactly where it crossed. It didn't have the same slope as a

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Gaussian process. That's why I said the Gaussian approximation was not a good approximation.
Q. I'm not talking about the Gaussian approximation. I'm talking about your simulation.
A. Yeah. So it had a different slope than a Gaussian process. It was diverging. I don't remember where it crossed.
MR. McDOLE: I object to that question to form.
BY MR. McANDREWS:
Q. Do you believe that it crossed to the left of your Scenario 1, shown on graph 2 on page 30?
A. I don't recall.
Q. Based on your expertise, do you believe it would have crossed the clipping threshold to the left of your Scenario 1 in graph 2?
A. I don't want to guess.
Q. You don't have any idea where that would show up?
A. I don't like that question that way. I said I don't want to guess.
Q. So you ran this quick simulation; right?
A. Mm-hmm.
Q. And you didn't save the results; right?
A. No.

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Q. And you didn't save the script?
A. The script, I am improving it and adding things to it, and I am overwriting the same program.
Q. Did you share the results with anyone?
A. I don't recall now. I don't recall.
Q. Were the results ever recorded in electronic or paper form?
A. So my computer ran a quick simulation, and it showed me a plot. I looked at it, and I said, "It's diverging. Now, let me focus on a case that's more interesting," because I see the Gaussian approximation is not a good approximation.
Q. Did you save that plot?
A. I don't -- I don't recall.
Q. You understand you're under oath; right?
A. I know. I know. I don't know if I saved that plot.
MR. McDOLE: Counsel, with all due respect --
THE WITNESS: I don't like that.
MR. McDOLE: Why don't we take a break, if you need to calm yourself down, but making implications that the witness is -- is violating his --
MR. McANDREWS: Spoliating evidence? I

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think we've got some pretty good evidence of that here. So, yes, I am implying that.
MR. McDOLE: Let's take a break.
MR. McANDREWS: Yes.
MR. McDOLE: You can calm down a little bit, Counsel. When you are ready and calmed down, let us know.
(Recess taken)
BY MR. McANDREWS:
Q. So Dr. Tellado, did you save, in any form, your MATLAB simulation script for the 18,000-foot loop scenario?
MR. McDOLE: Objection; asked and answered.
THE WITNESS: I don't recall.
BY MR. McANDREWS:
Q. Do you currently have, in any form, your MATLAB simulation script for the 18,000-foot loop scenario?
A. I have the script you have. That's my latest version.
Q. Do you have -- do you currently have, in any form, your MATLAB simulation script for the 18,000-foot loop scenario?
A. The form I have now is the one that you have.

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Q. So the answer is no?
MR. McDOLE: Objection; form.
THE WITNESS: Can you ask the question again?
BY MR. McANDREWS:
Q. Do you currently have, in any form, your MATLAB simulation script for the 18,000-foot loop scenario?
MR. McDOLE: Objection; asked and answered.
THE WITNESS: So what I did say last time? I don't recall what I have. I believe you have the same thing I have. That's what I recall.
BY MR. McANDREWS:
Q. And what I have is your MATLAB simulation script for the 12,000-foot loop scenario; right?
A. What you have -- no. No. Well, I don't know exactly what you have. You are pointing at something. I don't know what that is.
What the exhibit has is a model of what happens to a transmitter when 182 carriers are pseudorandom or random -- pseudorandom and 52 Shively carriers that are structured. And that applies to many combinations of high attenuations and/or crosstalk.
Q. Okay.

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A. There is no channel loop simulation in that code.
Q. Okay. Do you currently have, in any form, your MATLAB simulation script for a scenario in which there are 88 random carriers and 16 Shively carriers?
A. I don't recall. I believe I overwrote that code with newer versions of the code.
Q. Did you share with anyone, including your lawyers, a copy of your MATLAB simulation script for 88 usable carriers and 16 Shively carriers?
A. I don't recall.
Q. Did you save, in any form, the output of your MATLAB simulation of 88 usable carriers and 16 Shively carriers?
A. Repeat the question.
Q. Did you save, in any form, the output of your MATLAB simulation for the 88 random carriers and 16 Shively carriers?
A. I don't recall.
Q. Do you currently have in your possession, in any form, the output of your MATLAB simulation for the 88 usable carriers and 16 Shively carriers?
A. I don't recall.
Q. Did you share with anyone, in any form,

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including with your counsel, the output of your MATLAB simulation of 88 usable carriers and 16 Shively carriers?
A. Didn't you ask me that question already?
Q. No. I asked you whether you had it in your possession. Now I'm asking whether you shared it with anybody.
A. You said "with lawyers or" -- can you repeat all the questions, because --
Q. Sure.
A. -- it's the same answer, but...
Q. Did you share with anyone, in any form, including with your lawyers, the output of your MATLAB simulation of 88 usable carriers and 16 Shively carriers?
A. Repeat the question again.
Q. Did you share with anyone, in any form -- I'll leave out the lawyer part for now.
Did you share with anyone, in any form, the output of your MATLAB simulation of 88 usable carriers and 16 Shively carriers?
A. "Any form" means a plot, a result; right? Not just verbally saying it's not Gaussian?
Q. Correct. Some tangible form, electronic or paper.

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A. You're saying verbally, because I told my lawyers --
MR. McDOLE: You should not disclose any conversations that you have had with counsel.
THE WITNESS: Okay.
MR. McDOLE: If you can answer otherwise, feel free to do so.
THE WITNESS: So I do not recall giving them electronic copy.
BY MR. McANDREWS:
Q. Do you recall giving them a paper copy?
A. I don't recall giving them a paper copy.
MR. McANDREWS: Okay. So we'd like to make a request. If anybody has this simulation, whether it's the script or the output, we'd like to see it.
MR. McDOLE: What's your basis?
MR. McANDREWS: Because he concludes that it's not correct, the analysis that Dr. Short did, and he provides no basis in his report for that.
MR. McDOLE: Does he rely on something that you're asking for?
MR. McANDREWS: Yeah, he is relying on his quick simulation. He just testified to that.
MR. McDOLE: Well, we'll take it under advisement. I mean, is there a rule on which you're

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going to request to have a discovery request?
MR. McANDREWS: Well, I think I'm going to bring it to the Board, yes. I'm going to bring it to the Panel.
MR. McDOLE: Okay. Well, we'll take it under advisement.
MR. McANDREWS: Okay.
BY MR. McANDREWS:
Q. So can you tell me whether a scenario in which 88 random carriers are used with 16 Shively carriers -- and I'll narrow that a little bit -- it's 16 Shively characters where they are grouped into four groups of four -- can you tell me whether that would have a clipping characteristic that exceeds the 5.1 to the negative 5 clipping threshold you show in graph 2?
MR. McDOLE: Objection; form.
THE WITNESS: Repeat the question.
BY MR. McANDREWS:
Q. Can you tell me whether a scenario in which 88 random carriers are used with four groups of four of Shively carriers would have a clipping characteristic that exceeds 5.1 to the negative 5?
A. Repeat the question.
Q. Can you tell me whether a scenario in which

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88 random carriers are used with four groups of four Shively carriers would have a clipping characteristic that exceeds the 5.1 to the negative 5 clipping threshold?
A. As I said, the selection of random carriers, the power of the random carriers, the selection of the 16 carriers and the power of the 16 Shively carriers and the power increase is a function of many parameters. It is also a function of which part of the spectrum they are in.
Q. With 88 random carriers and four groups of four Shively carriers, will the symbol clipping rate exceed 5.1 to the negative 5 when the PAR is 14.2 dB?
A. I don't want to guess there.
Q. You don't have any inclination one way or the other?
A. I'm not going to guess.
Q. Let's talk about your selection of carriers. So I believe it's on page 21 where you illustrate your selection of random carriers, impaired carriers -- which we're calling Shively carriers -- and unusable carriers; correct?
Do you see that on page 21 of your declaration?

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A. Can you repeat the question?
Q. So let's do it this way: What are you illustrating on page 21 of your declaration?
A. What I am illustrating is an example of a loop that Shively would improve. And by selecting the parameters for this loop, I will demonstrate the Shively technique increases PAR.
Q. Okay. And you have brackets there that say "unimpaired carriers", "impaired carriers," and "useable carriers."
MR. McDOLE: Objection; form.
BY MR. McANDREWS:
Q. What are those intended to show?
A. Can you say that again?
Q. You have, in red brackets on page 21, a grouping of carriers that you label "unimpaired carriers," you have a grouping you label "impaired carriers."
Do you see that?
A. Mm-hmm.
Q. Yes or no?
A. Yes.
Q. Yes, you see that, okay.
And you have a grouping of carriers you label as "unusable carriers."

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the probability that carriers have the same structure.
And this is illustrating the probability that a small number of carriers line up -- of course, the MT -- the standard we keep talking about has many more than 64 carriers. So this is the probability that those carriers line up, the structured ones versus random ones.
The blue one is random groups, and the red is structured groups.
Q. Right. But the red groups, the probability of them lining up is only -- the only thing you're reporting here is whether the bits within that group will line up; correct? I'm sorry.
A. No.
Q. It's only reporting whether the carriers within that group will line up; correct?
A. All the carriers in that group.
Q. Right.
A. 64 of them in the case you mentioned. So that's a probability that all 64 carriers will have the -- line up.
Q. But, as you pointed out, there will be additional carriers other than the Shively carriers.
A. That's why I provided a simulation, to

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model the joint effect of the random ones and the structured ones.
This is all random versus all structure.
Q. Okay. Let's go to your Table 4 on page 16. And I believe you're reporting something similar here.
So when you have, in the right-hand column, that says "Shively frequency," and you intend by "Shively frequency" to mean the frequency that the Shively carriers --
A. Perfectly align.
Q. -- will perfectly align?
A. Mm-hmm.
Q. Okay? So when you say -- so in the first row, "Number of phase-aligned carriers, 4," you're reporting on one group of four; correct?
A. Yes, that 4 is one group -- 1-bits across four -- replicated four times.
Q. Okay. And so when you have one group, they'll obviously be aligned all the time; right?
A. Yes, you have four lined-up carriers.
Q. So this isn't a very interesting row, is it?
A. The first row just shows the fact that Shively has four carriers lined up even with 1-bits,

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and everybody shows the degradation with 1-bits.
Q. Okay. And the 4,000 times per second is simply that there are 4,000 symbols in a second; correct?
A. Yes, every DMT symbol will have that 1-bits replicated four times, so they will line up every time.
Q. Okay. But that doesn't speak to whether those 4 bits will line up with all of -- I'm sorry. It doesn't speak to whether those four carriers will align with the remaining random carriers; correct?
A. This section is to illustrate that when you have structural patterns, the probability of them lining up is much higher than random patterns. And then these patterns will be aggregated with the random ones. And then the simulation on page 30 is the one you should use for clipping probabilities in PAR degradation.
This is an illustration of the side effects of structured pilots.
Q. Okay. So when -- so in your last row there, you have 52 phase-aligned carriers; right? So you have 52 of them, and I assume that's 13 groups of four?
A. Yes.

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Q. Okay. And what you're saying is that once per second those 13 groups of four will align; right?
MR. McDOLE: Object to the form.
BY MR. McANDREWS:
Q. Will perfectly align; right?
What you're saying is that once per second all of the carriers in those 13 groups of four will align; right?
MR. McDOLE: Object to the form.
THE WITNESS: Ask the question again.
BY MR. McANDREWS:
Q. So are you intending to report that if there are 13 groups of four Shively carriers, that all of the carriers in those 13 groups of four will align once per second?
A. Again, this is an illustration of the worst-case alignment.
The better thing -- to actually see the true side effects of Shively is the plots in page 30. This is illustrating that those 32 -- if we pick the subset of 32 carriers, what's the probability that they have the same phase if they were random, and what's the probability they have the same phase if they have groups of four?

And this illustrates why the simulation shows that Shively degrades PAR. This is just an illustration.

The true PAR, you have to go to putting in random and putting Shively and doing joint simulation.

Q. So one of the rows in this table reports on 32 Shively carriers; is that right?

A. I see 32.

Q. Okay. But you didn't use 32 Shively carriers in your simulation; right?

A. I don't recall using 32. As you can see, this table is mostly incrementing by 4 or 8. It's just giving a sense of some examples. It doesn't have every example. It has 4, 8. It's missing 12. It has 16. It's missing 20. It has 24. It's missing 28. It has 32. It's missing 36. It's missing 40. It's missing 44. Then it has 48.

It has just a subset of groups of four between 4 and 52, just to keep the table a little bit smaller.

Probably going to have to take a break.

Q. Just let me make sure -- I think we can probably break here.

MR. McANDREWS: Okay. Why don't we take a

break.

(Lunch recess taken)

AFTERNOON SESSION

BY MR. McANDREWS:

Q. So I'm going to put in front of you a couple of exhibits. So we have what was previously marked as Cisco Exhibit CSCO 1034, and then we have two new exhibits, Exhibit 2010 and 2011. Put those in front of you.

(Exhibit 1034 previously marked for identification was referenced herein)

(Deposition Exhibits 2010 and 2011 were marked for identification)

BY MR. McANDREWS:

Q. I want to refer to these kind of as a group.

Sorry, can I see that?

All right. So do you recognize Exhibit 1034?

A. Yes.

Q. Can you tell me what that is?

A. That's my MATLAB I wrote.

Q. And this is the MATLAB code you wrote to simulate -- well, why don't you tell me. You wrote it to do what?

MR. McDOLE: Objection; form.

THE WITNESS: Please ask the question again.

BY MR. McANDREWS:

Q. You wrote the code to do what?

MR. McDOLE: Same objection. Objection to form.

THE WITNESS: I wanted to model the effect of having Shively tones.

BY MR. McANDREWS:

Q. Okay. And in this particular -- is this a MATLAB script?

A. It runs on MATLAB. It also runs on Octave, with a slight difference in compatibility.

Q. And which one did you write it on?

A. I ran it on -- I wrote it on MATLAB, and I tested it in MATLAB.

Q. Okay. And can you tell me what the variables are at the top of the first page of 1034?

A. So variable capital N equals 4 is the number of repetitions per bits. It's the Shively replication rate.

Q. So this is the situation where you use four tones to replicate a single bit?

A. Mm-hmm.

Q. Okay. And what is --

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A. Capital N equals 256 is the max number of tones of subcarriers for 512 real valued DMT system --
Q. Okay.
A. -- which is what is used in the ADSL standard.
Q. Okay.
A. Zl, little L, equals 6 is the number of low frequency tones that would be set to 0.
Q. Okay.
A. Capital Z little S is, in this case, 13 times capital M. Capital M being the Shively replication rate selected for this example.
Q. And those -- that corresponds to the tones that we have been referring to today as either Shively tones or impaired tones?
A. Yes. The code itself has a common saying, Shively tones, yes.
Q. Okay.
A. So it's basically 13 times capital M Shively tones. Capital Z of capital H equal 15 is the number of unused high frequency tones.
Q. Okay. And so these variables correspond to the scenario you used in your reply declaration, where you looked at 182 random tones and 13 groups

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of four Shively tones; is that right?
A. Yes.
Q. And then the output was what we looked at in your declaration, the, I guess, bluish-green curve in the far right; is that correct?
A. So there is four different scenarios. This code executes four different scenarios at the same time.
Q. And what are the four different scenarios?
A. So Scenario 1 has 250 pseudorandom carriers. Scenario 2 is a Gaussian process using the MATLAB library function. Scenario 3 is the case of having 182 QAM-4 carriers. And Scenario 4 has 182 QAM-4 carriers and the 13 times 4, or 52, Shively carriers.
Q. Okay. And where I do look on this page to find the four different scenarios that it runs at the same time?
A. So before the 4 loop, which generates capital K number of DMT symbols, there is actually 4 vectors denoted PAR, PAR little Z, PAR little S, PAR little G. That vector is going to keep track of the PAR of each one of the four scenarios. So as the code is running, it will start loading the peak power for each one of those four scenarios and try

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capital K times -- simulated capital K times.
So that's the initialization. Then there is a 4 loop that goes from little K equals 1 to capital K, and it's going to go and generate all four interleaved. As it's executing, it's doing each one of the four, and then it starts again.
Q. Okay. Now, could you, like, take a look at Exhibit 2010.
And I'll represent to you that you haven't seen this before, but can you take a brief look through this script and tell me whether it appears to follow your script?
A. I could not say that. Anybody that's written code before knows that a comma -- anything could change the behavior of a code. So it's not possible for me, looking at this, to know it's equivalent.
Q. Okay. Do you see at the top there are two lines highlighted in yellow?
A. Yes.
Q. And I'll represent to you that that was intended to indicate the only two variables that were changed in this script with respect to yours.
A. I see there is new instructions added.
Q. Where do you see that?

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A. I see an F flash. No.
I cannot. It's difficult like this. This is not how people write software. They have tools that do these things for them.
Q. Okay. Let me refer you to Exhibit 2011.
A. Okay.
Q. So you wouldn't be able to confirm for me, sitting here today, one way or the other whether the code in 2010 is -- runs the same functions as your code in 1034; you wouldn't be able to do that?
A. No, I wouldn't be able to do that, no.
Q. Okay. Can you look at Exhibit 2011.
A. Yes.
Q. Okay. Can you compare 2011 to your -- the figure that you provide on page 30 of your declaration?
A. Yes.
Q. Does the graph in 2011 for scenarios one, two, three and four -- does it look like it accurately corresponds to your scenarios one, two, three and four?
A. I can't say accurately. It has a similar look.
Q. Do each of the curves for Scenarios 1, 2, 3, and 4 look to be approximately the same as your

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curves 1, 2, 3, and 4?
MR. McDOLE: Objection; form.
THE WITNESS: I would actually like to have the numerical quantities compared against these numerical quantities to say if they are the same or approximately the same or kind of the same.
BY MR. McANDREWS:
Q. But your graph on page 30 doesn't report numerical quantities, does it?
A. I have given you the code.
Q. Right. But the graph itself doesn't report numerical quantities, does it?
A. It does. I gave you differences of PAR degradation from turning on Shively tones. That was a numerical amount. I say how much dB's and what percentage. Those were numerical values picked on the plots.
Q. No, but I'm asking about the graph, the graph itself.
A. But the comments I make about the graph are how much worse the Shively carriers are than not having Shively carriers, and I have numerical values for those points.
Q. Okay. But you can't tell me, sitting here today, whether these curves in Exhibit 2010 are

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approximately the same as the curves in the figure on page 30?
A. They look similar.
Q. Okay. Now, I'm going to represent to you that Scenario 5 was run using the script in 2010.
Does that curve look like a good approximation of what would result from running your script using 16 Shively tones and 88 random carriers?
MR. McDOLE: Objection; form.
THE WITNESS: I would not want to guess that.
BY MR. McANDREWS:
Q. So you wouldn't -- let me ask it this way: Would you know intuitively that 88 random carriers and 16 Shively carriers would be to the left on the graph of Scenario 2?
MR. McDOLE: Objection; form.
THE WITNESS: As I mentioned earlier, the repeating -- the repeating -- the replicated bits that Shively introduces has a non-Gaussian behavior and it separates from the Gaussian decay. So I cannot tell if this is correct.
BY MR. McANDREWS:
Q. You don't know, just intuitively, that a

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scenario with 88 QAM carriers and 16 Shively carriers would be to the left of the Gaussian process, Scenario 2?
MR. McDOLE: Objection; form, asked and answered.
Go ahead.
THE WITNESS: I said many times, when you introduce structured carriers, it generates trouble.
I cannot tell you here whether this thing has modeled the increase in PAR from the Shively carriers correctly. I cannot tell.
BY MR. McANDREWS:
Q. I'm not asking you about whether this is modeled. I'm asking you intuitively, intuitively.
A. I'm not going to guess.
Q. You don't know intuitively?
A. I'm not going to guess.
MR. McDOLE: Objection; form.
BY MR. McANDREWS:
Q. I'm not asking you to guess. You have mentioned the word "intuitively" numerous times in your declaration.
Would you know -- would you know intuitively that 88 random carriers and 16 Shively carriers would be to the left of Scenario 2?

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A. I'm not going to guess.
Q. You're not going to guess at whether you would know intuitively?
MR. McDOLE: Objection; form.
THE WITNESS: I'm not going to -- I'm not going to give an intuitive answer to a problem like this one.
BY MR. McANDREWS:
Q. You don't know one way or the other intuitively whether it would be to the left?
MR. McDOLE: Objection; form.
THE WITNESS: I'm not going to guess.
BY MR. McANDREWS:
Q. Do you know?
A. As I mentioned several times today, the 16 repeating carriers have a structure that make the clipping probability higher than a Gaussian.
Q. So you don't know?
MR. McDOLE: Objection; form.
THE WITNESS: I don't -- I don't know what?
BY MR. McANDREWS:
Q. You don't know intuitively whether the curve for 88 QAM carriers and 16 Shively carriers would be to the left of Scenario 2?
MR. McDOLE: Objection; form.

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THE WITNESS: Can you rephrase the question?
BY MR. McANDREWS:
Q. Do you know intuitively whether Scenario 5, with 88 QAM carriers and 16 Shively carriers, would be to the left of Scenario 2, the Gaussian curve?
MR. McDOLE: Objection; form.
THE WITNESS: With 16 structured Shively carriers, I could not guess if it's going to be to the left or the right of that curve you mentioned.
BY MR. McANDREWS:
Q. Do you know intuitively whether 88 random carriers and 16 Shively carriers would have a lower probability of clipping than Scenario 2?
MR. McDOLE: Objection; form.
THE WITNESS: No, I'm not going to guess.
BY MR. McANDREWS:
Q. So you don't know intuitively the answer to that question?
A. I'm not --
MR. McDOLE: Objection; form.
THE WITNESS: I'm not -- sorry. I'm not going to guess the answer to that question.
BY MR. McANDREWS:
Q. I'm not asking you whether you will guess

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or not. I want to know if you know intuitively.
MR. McDOLE: Objection; form.
BY MR. McANDREWS:
Q. Do you know intuitively what the answer to that question is?
MR. McDOLE: Objection; form.
THE WITNESS: I'm not going to guess.
BY MR. McANDREWS:
Q. You're not going to guess at my question of whether you know or not?
MR. McDOLE: Objection; form.
THE WITNESS: I don't know.
MR. McDOLE: Harassing the witness.
MR. McANDREWS: I'm not harassing the witness.
MR. McDOLE: Yes, you are, Counsel.
BY MR. McANDREWS:
Q. No. I'm not asking you to guess at what you know. I'm asking you to tell me what you know and what you don't know.
MR. McDOLE: Objection to form, harassing the witness.
BY MR. McANDREWS:
Q. Do you know intuitively -- do you know one way or the other intuitively whether Scenario 5

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would present a lower chance of clipping than Scenario 2?
MR. McDOLE: Objection; form, asked and answered, harassing the witness.
THE WITNESS: What I do know is the plots that I modeled, those are in the record, and those are accurate.
BY MR. McANDREWS:
Q. Okay. Do you know one way or the other -- either you know it intuitively or you don't know it intuitively -- whether Scenario 5 presents a lower chance of clipping than Scenario 2?
MR. McDOLE: Objection; form, harassing the witness.
THE WITNESS: Can you repeat the question? You've said it too many times.
BY MR. McANDREWS:
Q. Do you know intuitively whether Scenario 5 presents a lower chance of clipping than Scenario 2?
A. I don't want to guess.
MR. McDOLE: Objection; form.
BY MR. McANDREWS:
Q. I don't know what you're guessing at.
A. I don't want to guess at the question.
Q. I'm asking about your knowledge. This is

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your knowledge. I'm not asking you to guess whether it is or isn't. I'm asking whether you know.
A. I don't know.
Q. Do you know intuitively? You don't know intuitively?
MR. McDOLE: Objection; form.
BY MR. McANDREWS:
Q. You don't know intuitively. So let me state it the other way.
You're telling me that you don't know intuitively whether Scenario 5 presents a lower chance of clipping than Scenario 2; is that right?
MR. McDOLE: Objection; form.
THE WITNESS: I have to guess at an answer to know if intuitively I could get it.
BY MR. McANDREWS:
Q. If you could take a look at -- we're back in Exhibit 1026, your declaration. If you could take a look at paragraph 57.
So is it your opinion that, in Stopler, that QAM symbols are randomized one with respect to the other within a single DMT symbol?
A. Ask the question again.
Q. Is it your opinion that -- in Stopler, that QAM symbols are randomized one with respect to the

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portion of a symbol to user one and a portion of a symbol to user two?
A. A DMT transmitter has to know where the boundaries of the DMT symbols are to transmit them. But to phase-scramble all of the symbols in the same DMT symbol by the same amount, the phase scrambler has to be synchronized with that circuit, which I don't see and I don't recall seeing.
Q. At the time of the invention of the '158 and '243 patents, were there multiple ways of reducing PAR that were known to those of skill in the art?
A. Yes.
MR. McANDREWS: Can we mark this as 2012.
(Deposition Exhibit 2012 was marked for identification)
MR. McDOLE: Thank you.
BY MR. McANDREWS:
Q. Exhibit 2012 has been placed in front of you, Dr. Tellado.
Can you tell me what Exhibit 2012 is?
A. This one says United States Patent by Tellado, et al, and it's titled "Peak to Average Power Ratio Reduction," and it's filed April 20th, 1998.

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Q. Okay. And the inventors listed there are -- include Jose Tellado of Mountain View.
Is that you?
A. That's me.
Q. This is your patent?
A. Yes.
Q. And it's you and John Cioffi?
A. Yes, that's my Ph.D. advisor from Stanford.
Q. Do you recall this patent?
A. Yes. I don't remember all the details. It was 20 years ago.
Q. If you can turn to column 1 of that patent. And starting on about line, let's call it, 47 of column 1.
A. 47. Okay. Column 1, line 47.
Q. I'm going to read this to you, and I want you to confirm that I have accurately read it.
So it states:
"One method randomly shuffles" --
A. Wait. Wait. Wait. You said column 1?
Q. Column 1, about line 47.
A. Yes.
Q. It says:
"One method randomly shuffles the phase of the signals 10(1)-10(n) at each carrier

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frequency f(1)-f(n). Random shuffling does not completely eliminate the problem, although randomizing has been shown to somewhat reduce the peak to average power ratio to an extent. Random shuffling also requires performing an additional IFFT. In addition to not completely reducing the peak to average power ratio to a practical point, that particular method also requires that additional information, side information, be sent along with the transmitted signal. In order for the receiver to be able to decode the transmitted signal the receiver must also know how the signals 10(1)-10(n) were randomized. Thus, the randomization scheme requires extra bandwidth to transmit the side information and does not effectively reduce the peak to average power ratio."
Do you see that?
A. Yes.
Q. Did I accurately read that?
A. I believe so.
MR. McANDREWS: Thank you. No further questions.

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EXAMINATION
BY MR. McDOLE:
Q. Dr. Tellado, my name is Jamie McDole. I represent Cisco. I have a couple of questions I'd like to ask you.
Do you recall earlier in your testimony discussion about your thesis?
A. Yes.
Q. What was the subject matter of your thesis?
MR. McANDREWS: Objection; outside the scope. Objection; relevance.
THE WITNESS: Peak-to-average power reduction for multicarrier modulation.
MR. McDOLE: Can I have those?
(Exhibit 1025 previously marked for identification was referenced herein)
BY MR. McDOLE:
Q. I'm going to hand you what's been previously marked as Exhibit 1025.
Dr. Tellado, can you please describe what Exhibit 1025 is?
A. Oh. I can't possibly look through all 154 pages. But scanning through it, I believe -- I believe it's a copy of my thesis.
Q. Okay. I'd like to have you turn to page

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166 of -- or 152 of your thesis marked as Exhibit 1025.
MR. McANDREWS: I'm just going to lodge a continuing objection that is this outside the scope and it's not relevant to the proceedings.
THE WITNESS: What page?
BY MR. McDOLE:
Q. 152.
A. Yes.
Q. Do you see reference 77 at the bottom of your thesis marked as Exhibit 1025?
A. Citation 77, you said?
Q. Yes.
A. I see it.
Do you want me to read it to you?
Q. I'm going to hand you a document that's been previously marked as Cisco -- or Exhibit 1023.
(Exhibit 1023 previously marked for identification was referenced herein)
BY MR. McDOLE:
Q. Dr. Tellado, can you confirm whether Exhibit 1023 is the same citation that is at citation 77 of your thesis marked as Exhibit 1025?
MR. McANDREWS: Again, same objection. Exhibit 1023 is outside the scope. Also an

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objection to relevance.
THE WITNESS: The page numbers and the title and the author match, so I believe it's the same.
BY MR. McDOLE:
Q. Okay. Now, is it okay if I refer to Exhibit 1023 as the Mestdagh reference? Will you understand I'm referring to Exhibit 1023?
A. Yes.
Q. Does the Mestdagh reference discuss phase scrambling to reduce PAR?
MR. McANDREWS: Objection; leading. Objection; outside the scope, relevance.
THE WITNESS: (Witness reviewing document.)
Okay. So I'm reading from column 2 of page 1234, the bottom paragraph, starting on line 3:
"Instead, the phasor of each QAM-modulated carrier is changed by means of a fixed phasor-transformation and a new DMT symbol is generated by the IFFT. By careful selection of the phasor-transformation, the probability of clipping this new symbol...will be very low."
Another paragraph from page 1235, column 1, the third paragraph:

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"Many phasor-transformations can be used. An easy-to-implement fixed random phasor transformation (known at the receiver) will be considered in what follows. Several other (more involved) transformations can be used as well without affecting the main results presented here."
Is that enough?
BY MR. McDOLE:
Q. Dr. Tellado, are the passages you've just read out of the Mestdagh reference in relation to phase-scrambling to reduce PAR?
MR. McANDREWS: Objection; leading. Objection; outside the scope, relevance.
THE WITNESS: My interpretation of "the phasor of each QAM-modulated carrier is changed by means of a fixed phasor-transformation and a new DMT symbol is generated" -- I interpret that as each QAM-modulated carrier within a DMT symbol has a phase transformation to reduce PAR.
BY MR. McDOLE:
Q. Does the Mestdagh reference provide an example of people trying to beat Gaussian-level performance in peak-to-average ratio in the 1990s?
MR. McANDREWS: Objection; leading.

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Objection; outside the scope, relevance, foundation, competence.
THE WITNESS: So Mestdagh starts with -- it does multiple phase transformations, so that it gets better-than-Gaussian performance. It tries to beat the Gaussian performance by repeating the process multiple times.
BY MR. McDOLE:
Q. I'd like to have you go back to your thesis and turn to page 153 of your thesis, and specifically have you look at reference 82.
A. Yes.
Q. I'm going to hand you a document that's been previously marked as Exhibit 1024.
MR. McDOLE: Counsel?
(Exhibit 1024 previously marked for identification was referenced herein)
BY MR. McDOLE:
Q. Dr. Tellado, could you compare Exhibit 1024 and state whether Exhibit 1024 is the same reference as reference 82 of your thesis, which has been marked as Exhibit 1025?
MR. McANDREWS: Continuing objection to Exhibit 1024 as being outside the scope of either of Dr. Tellado's attempts at direct testimony and

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either cross-examination that's been taken of him. Relevance.

THE WITNESS: The authors match, the titles match, the page numbers match. So I believe it's the same reference.

BY MR. McDOLE:

Q. Okay. If I refer to Exhibit 1024 as the Muller reference, will you understand I'm referring to Exhibit 1024?

A. Yes.

Q. Dr. Tellado, does the Muller reference disclose phase-scrambling to reduce PAR?

MR. McANDREWS: Objection; leading. Objection; outside the scope, foundation.

THE WITNESS: Yes. If you look at -- for example, at Figures 1 or Figures 2 -- for example, let's start with Figure 1 -- it has a bit source going to a serial-to-parallel conversion, a use of bit stream coding and interleaving and mapping.

BY MR. McDOLE:

Q. And is Figure 1 entitled?

A. "PAR reduction in SLM-OFDM," which is a multicarrier flavor.

Q. And if I could have you turn to Figure 2 on the Muller reference, could you please state what

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the Figure 2 is entitled?

A. Figure 2 is called "PAR Reduction in PTS-OFDM."

And "OFDM" stands for "orthogonal frequency division multiplexing."

Q. Is the Muller reference another example of people trying to beat Gaussian-level performance in peak-to-average ratio in the 1990s?

MR. McANDREWS: Objection; foundation, relevance, leading.

THE WITNESS: So if you look at Figure 3 or Figure 4 -- Figure 3, called "Probability that the PAR of a randomly generated 128-carrier OFDM transmit sequence exceeds X0 for U IDFTs in SLM and V IDFTs in PTS with W equals 4."

And this plots in the X axis is the amplitude of the PAR, and the Y axis is the probability of clipping.

And if you look at the rightmost plots, they have the theory, which I don't have time to read, but my assumption is, theory would be the ideal distribution of either Gaussian or Rayleigh.

And then there is another one that's just hugging it, which is the case for a random OFDM symbol. And then all Muller's algorithms are better

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than the vanilla original pseudorandom OFDM case. And he has multiple variations of these two algorithms that use phase rotations to reduce PAR below Gaussian distribution.

BY MR. McDOLE:

Q. Is Figure 3 of the Muller reference similar to the plots of the simulations that you provided in your declaration?

MR. McANDREWS: Objection; leading, relevance, outside the scope.

THE WITNESS: So my simulations are based on a DMT transmitter where the output are real-valued.

This paper was -- as opposed to the Mestdagh one, this one has been done for a multicarrier system that is complex-valued. And this is what the wireless community uses, and they call it OFDM.

So the distribution will be slightly different, but the comparison of random or pseudorandom theoretical and then how much the PAR reduces with these techniques is a similar type of plots, except that all these techniques, the performance is better than just random phase -- phased OFDM.

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BY MR. McDOLE:

Q. Okay. If I could have you turn to Figure 6 on page 18 of your declaration.

A. Sorry, which page?

Q. Figure 6 of page 18 of your declaration, which has been marked as Exhibit 1026.

Are you there?

A. Page 18, Figure 6, yes.

Q. Holding all variables constant, if you change only the maximum transmission power, would the lines on Figure 6 change?

A. Yes.

Q. Dr. Tellado, you were asked a lot of questions about the Shively reference today.

Do you recall that?

A. Yes.

Q. Did counsel for TQD ever provide you a copy of the Shively reference when you requested it?

A. I don't -- no.

Q. If I could have you turn to Exhibit 2010. And if I could have you also have Exhibit 2011 out.

A. This is all the exhibits I got today; right?

Q. Yes. So this is 2010. This is 2011. There you go.

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Now, starting with Exhibit 2010, can I draw your attention down to the bottom of the page with one of the code lines that's -- the first word is semilogy.
A. Yes, I see that line.
Q. Semilogy, that line refers to an axis.
What is an axis?
A. Axis is the vector I use to generate the histogram of the PAR points. Further up, there's -- you see the axis equals 6:0.4:20. So it's a vector I use to bend the PAR samples to make this plot.
Q. How many axes are identified in the code for semilogy on Exhibit 10- -- 2010?
A. These lines are wrapping around, but I only see four.
Q. If I could have you turn now to Exhibit 2011.
How many scenarios did Counsel provide you -- strike that.
If I could have you turn to Exhibit 2011.
A. Yes, I have that.
Q. How many scenarios are represented on Exhibit 2011?
A. I see one, two, three, four and five. So a total of five scenarios.

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Q. And those are represented by five lines; correct?
A. Five scenarios, five lines, yes.
Q. Is there any way the code depicted on Exhibit 2010 could have plotted all five lines on Exhibit 2011?
MR. McANDREWS: Objection; foundation.
THE WITNESS: So I don't see the legend for Scenario 5. I don't see the axis for Scenario 5. So this code cannot generate this plot.
MR. McDOLE: No further questions.
MR. McANDREWS: Let's take a brief break here.
(Recess taken)
MR. McANDREWS: We have no further questions at this time.
MR. McDOLE: We'll reserve signature.
MR. McANDREWS: Thank you, Dr. Tellado.
(Time noted: 3:38 p.m.)

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DECLARATION UNDER PENALTY OF PERJURY

I, JOSE TELLADO, Ph.D., do hereby certify under penalty of perjury that I have read the foregoing transcript of my deposition taken on June 20, 2017; that I have made such corrections as appear noted herein in ink, initialed by me; that my testimony as contained herein, as corrected, is true and correct.

DATED this day of 2017, at , California.

JOSE TELLADO, Ph.D.

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REPORTER'S CERTIFICATE

I, CYNTHIA MANNING, a Certified Shorthand Reporter of the State of California, do hereby certify:

That the foregoing proceedings were taken before me at the time and place herein set forth; that any witnesses in the foregoing proceedings, prior to testifying, were placed under oath; that a verbatim record of the proceedings was made by me using machine shorthand which was thereafter transcribed under my direction; further, that the foregoing is an accurate transcription thereof.

I further certify that I am neither financially interested in the action, nor a relative or employee of any attorney of any of the parties.

Before completion of the deposition, review of the transcript [X] was [ ] was not requested. If requested, any changes made by the deponent (and provided to the reporter) during the period allowed are appended hereto.

In witness whereof, I have subscribed my name this 21st day of June 2017.

CYNTHIA MANNING, CSR No. 7645, CCRR, CLR

However, the specification of the ’158 patent describes a “conventional multicarrier communications system” as using a “combination of multiple carriers.” Ex. 1001, 1:33-47. Consistent with the specification’s description and for the purposes of this proceeding, a POSITA would have understood that the broadest reasonable interpretation of “multicarrier” includes “multiple carriers.” Ex. 1009, p. 20.

2. *“transceiver”* (claims 1-28):

The ’158 patent does not expressly define a transceiver. Ex. 1009, p. 21. But the ’158 specification states that “DMT transceiver 10 includes a DMT transmitter 22 and a DMT receiver 26.” Ex. 1001, 3:27-39. The ’158 specification also states that a “transceiver” may be a modem. Ex. 1001, 1:42 & 3:30-53. A computer dictionary defines “transceiver” as “any device that transmits and receives.” Ex. 1014, p. 709. Consistent with the ’158 specification and the dictionary definition for the transceiver, and for the purposes of this proceeding, a POSITA would have understood that the broadest reasonable interpretation of “transceiver” includes a “device, such as a modem, with a transmitter and a receiver.” Ex. 1009, p. 23.

C. Statutory Grounds for Challenges

Challenge #1: Claims 1, 2, 4, 15, 16, and 18 are obvious under 35 U.S.C. § 103(a) over Shively (Ex. 1011) in view of Stopler (Ex. 1012). Shively was filed on December 31, 1997. *See* Ex. 1011. Stopler was filed on February 26, 1999. *See* Ex.

1012. Accordingly, both Shively and Stopler are prior art under § 102(e).

Challenge #2: Claims 3, 5, 14, 17, 19, and 28-30 are obvious under 35 U.S.C. § 103(a) over Shively in view of Stopler, and further in view of Gerszberg (Ex. 1013). Gerszberg was filed on December 31, 1997. *See* Ex. 1013. Accordingly, Gerszberg is prior art under § 102(e).

Challenge #3: Claims 6, 9, 10, 12, 20, 23, 24, and 26 are obvious under 35 U.S.C. § 103(a) over Shively in view of Stopler, and further in view of Bremer (Ex. 1017). Bremer issued on May 8, 1990. *See* Ex. 1017. Accordingly, Bremer is prior art under § 102(b).

Challenge #4: Claims 8, 11, 13, 22, 25, and 27 are obvious under 35 U.S.C. § 103(a) over Shively in view of Stopler, further in view of Bremer, and further in view of Gerszberg.

Challenge #5: Claims 7 and 21 are obvious under 35 U.S.C. § 103(a) over Shively in view of Stopler, further in view of Bremer, and further in view of Flammer. Flammer issued on May 7, 1996, and is prior art under § 102(b). *See* Ex. 1019.

D. Level of Ordinary Skill in the Art

The level of ordinary skill in the art may be reflected by the prior art of record. *See Okajima v. Bourdeau*, 261 F.3d 1350, 1355 (Fed. Cir. 2001); *In re GPAC Inc.*, 57 F.3d 1573, 1579 (Fed. Cir. 1995). Here, the person of ordinary skill

Ex. 1009, p. 43; Ex. 1012, Fig. 5 (annotated).

Second, as analyzed above in portions [1.1] and [1.2], Shively teaches modulating each of multiple carriers using quadrature amplitude modulation (QAM). It would have been obvious to a POSITA to employ Stopler's phase scrambling techniques in Shively's transmitter. Ex. 1009, p. 45. Thus, Shively and Stopler render obvious "a method for scrambling the phase characteristics of the carrier signals." Ex. 1009, p. 45.

[1.4] "transmitting the plurality of data bits from the first transceiver to the second transceiver;"

Shively and Stopler each render this limitation obvious.

First, as analyzed above in portion [1.0], Shively teaches a transmitting modem that is a "first transceiver" and a receiving modem that is a "second transceiver." Ex. 1009, pp. 45. Shively further teaches that the transmitting modem sends digital data to the receiving modem:

> [T]he invention provides a ***transmitting modem*** receiving digital data from a data source, ***modulating carriers to represent the digital data***, and applying a resulting modulated signal to a channel connectable ***to a receiving modem***.

Ex. 1011, 8:56-60.

As analyzed above in portion [1.1], it would have been obvious to a POSITA that Shively's digital data are "data bits." Ex. 1009, p. 46. Thus, Shively renders

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Paper 7
Entered: November 4, 2016

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CISCO SYSTEMS, INC.,
Petitioner,

v.

TQ DELTA, LLC,
Patent Owner.

Case IPR2016-01021
Patent 8,718,158 B2

Before SALLY C. MEDLEY, KALYAN K. DESHPANDE, and TREVOR M. JEFFERSON, *Administrative Patent Judges.*

MEDLEY, *Administrative Patent Judge*.

DECISION
Institution of *Inter Partes* Review
37 C.F.R. § 42.108

I. INTRODUCTION

Cisco Systems, Inc. (“Petitioner”) filed a Petition requesting an *inter partes* review of claims 1–30 of U.S. Patent No. 8,718,158 B2 (Ex. 1001, “the ’158 patent”). Paper 2 (“Pet.”). TQ Delta, LLC (“Patent Owner”) filed a Preliminary Response. Paper 6 (“Prelim. Resp.”). Institution of an *inter partes* review is authorized by statute when “the information presented in the petition . . . and any response . . . shows that there is a reasonable likelihood that the petitioner would prevail with respect to at least 1 of the claims challenged in the petition.” 35 U.S.C. § 314(a); *see* 37 C.F.R. § 42.108. Upon consideration of the Petition and Preliminary Response, we conclude the information presented shows there is a reasonable likelihood that Petitioner would prevail in establishing the unpatentability of claims 1–30 of the ’158 patent.

A. Related Proceedings

Petitioner indicates that the ’158 patent is the subject of several pending judicial matters. Pet. 1.

B. The ’158 Patent (Ex. 1001)

The ’158 patent relates to multicarrier communications systems that lower the peak-to-average power ratio (PAR) of transmitted signals. Ex. 1001, 1:28–31. A value is associated with each carrier signal, and a phase shift is computed for each carrier signal based on the value associated with that carrier signal. *Id.* at 2:38–41. The value is determined independent of the input bit value carried by the carrier signal. The computed phase shift value is combined with the phase characteristic of that carrier signal to substantially scramble the phase characteristics of the carrier

signals. *Id.* at 2:38–45. Figure 1 illustrates the multicarrier communication system and is reproduced below:

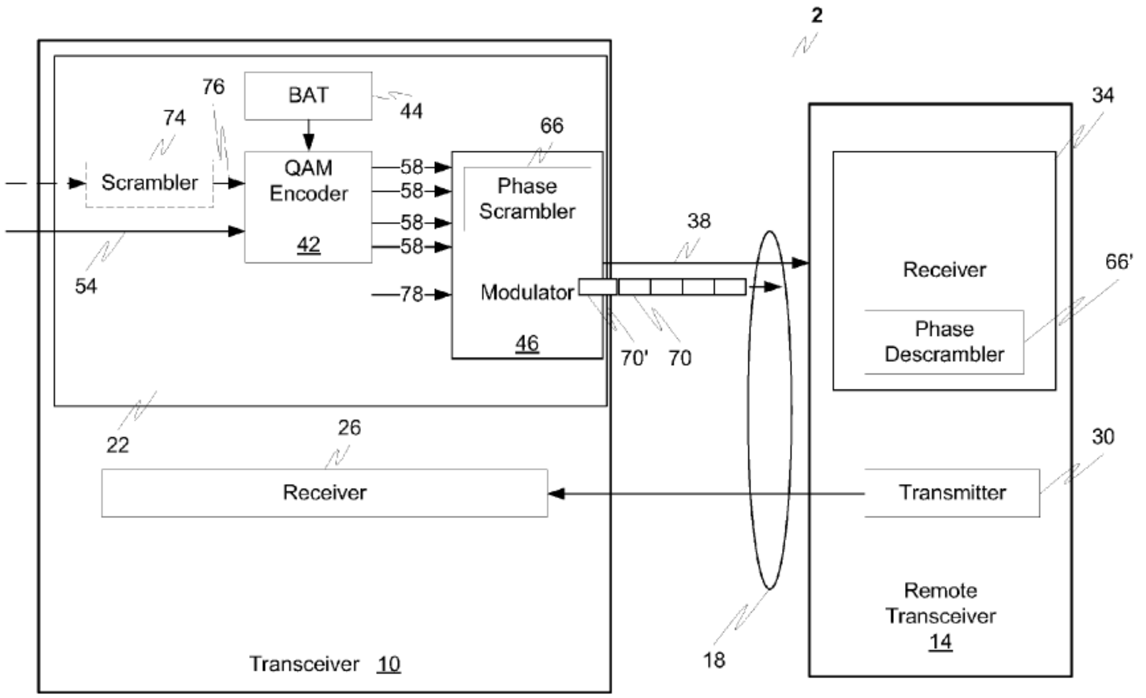

FIG. 1

Figure 1 illustrates the multicarrier communication system, digital subscriber line (DSL) communication system 2, which includes discrete multitoned (DMT) transceiver 10 communicating with remote transceiver 14 over communication channel 18 using transmission signal 38 having a plurality of carrier signals. *Id.* at 3:27–31. DMT transceiver 10 includes DMT transmitter 22 and DMT receiver 26. *Id.* at 3:31–32. Remote transceiver also includes transmitter 30 and receiver 34. *Id.* at 3:32–34. DMT transmitter 22 transmits signals over communication channel 18 to receiver 34. *Id.* at 3:40–42.

DMT transmitter 22 includes a quadrature amplitude modulation (QAM) encoder 42, modulator 46, bit allocation table (BAT) 44, and phase

scrambler 66. *Id.* at 3:53–56. QAM encoder 42 has a single input for receiving serial data bit stream 54 and multiple parallel outputs to transmit QAM symbols 58 generated by QAM encoder 42 from bit stream 54. *Id.* at 3:65–4:1. Modulator 46 provides DMT modulation functionality and transforms QAM symbols 58 into DMT symbols 70. *Id.* at 4:12–14. Modulator 46 modulates each carrier signal with a different QAM symbol 58, and, therefore, this modulation results in carrier signals having phase and amplitude characteristics based on QAM symbol 58. *Id.* at 4:15–18. Modulator 46 also includes phase scrambler 66 that combines a phase shift computed for each QAM-modulated carrier signal with the phase characteristics of that carrier signal. *Id.* at 4:31–34.

C. Illustrative Claim

Petitioner challenges claims 1–30 of the ’158 patent. Claims 1 and 15 are independent claims. Claims 2–14 and 29 depend, either directly or indirectly, from claim 1, and claims 16–28 and 30 depend, either directly or indirectly, from claim 15. Claim 1 is reproduced below.

> 1. In a multicarrier modulation system including a first transceiver in communication with a second transceiver using a transmission signal having a plurality of carrier signals for modulating a plurality of data bits, each carrier signal having a phase characteristic associated with at least one bit of the plurality of data bits, a method for scrambling the phase characteristics of the carrier signals comprising:
>
> transmitting the plurality of data bits from the first transceiver to the second transceiver;
>
> associating a carrier signal with a value determined independent of any bit of the plurality of data bits carried by the

carrier signal, the value associated with the carrier signal determined by a pseudo-random number generator;

determining a phase shift for the carrier signal at least based on the value associated with the carrier signal;

modulating at least one bit of the plurality of data bits on the carrier signal; and

modulating the at least one bit on a second carrier signal of the plurality of carrier signals.

Ex. 1001, 10:59–11:11.

D. The Alleged Grounds of Unpatentability

The information presented in the Petition sets forth proposed grounds of unpatentability of claims 1–30 of the ’158 patent under 35 U.S.C. § 103(a) as follows (Pet. 9–10):[1]

References	**Claims Challenged**
Shively[2] and Stopler[3]	1, 2, 4, 15, 16, and 18
Shively, Stopler, and Gerszberg[4]	3, 5, 14, 17, 19, and 28–30
Shively, Stopler, and Bremer[5]	6, 9, 10, 12, 20, 23, 24, and 26
Shively, Stopler, Bremer, and Gerszberg	8, 11, 13, 22, 25, and 27

[1] Petitioner supports its challenges with the Declaration of Dr. Jose Tellado. Ex. 1009.
[2] U.S. Patent No. 6,144,696; issued Nov. 7, 2000 (Ex. 1011) (“Shively”).
[3] U.S. Patent No. 6,625,219 B1; issued Sept. 23, 2003 (Ex. 1012) (“Stopler”).
[4] U.S. Patent No. 6,424,646 B1; issued July 23, 2002 (Ex. 1013) (“Gerszberg”).
[5] U.S. Patent No. 4,924,516; issued May 8, 1990 (Ex. 1017) (“Bremer”).

References	Claims Challenged
Shively, Stopler, Bremer, and Flammer[6]	7 and 21

II. ANALYSIS

A. Claim Construction

The Board interprets claims of an unexpired patent using the broadest reasonable construction in light of the specification of the patent in which they appear. *See* 37 C.F.R. § 42.100(b); Office Patent Trial Practice Guide, 77 Fed. Reg. at 48,766. Under the broadest reasonable construction standard, claim terms are given their ordinary and customary meaning, as would be understood by one of ordinary skill in the art in the context of the entire disclosure. *In re Translogic Tech. Inc.*, 504 F.3d 1249, 1257 (Fed. Cir. 2007).

"multicarrier"

Each of independent claims 1 and 15 recites a "multicarrier." Petitioner proposes that we interpret the phrase to include "multiple carriers." Pet. 8–9. Petitioner arrives at its proposed interpretation by explaining that although the term is not expressly defined, the Specification of the '158 patent describes a conventional multicarrier communications system as using a combination of multiple carriers. *Id*. at 9 (citing Ex. 1001, 1:33–47). Patent Owner argues that the term "multicarrier" need not be interpreted to render a decision on whether to institute trial. Prelim. Resp. 11. We determine that it is not necessary to interpret the term "multicarrier" for purposes of this decision.

[6] U.S. Patent No. 5,515,369; issued May 7, 1996 (Ex. 1019) ("Flammer").

"transceiver"

Each of independent claims 1 and 15 recites a "transceiver." Petitioner proposes that we interpret transceiver to include "a device, such as a modem, with a transmitter and a receiver." Pet. 9. Petitioner arrives at its proposed interpretation by explaining that the word "transceiver" is a combination of the words transmitter and receiver and that the specification of the '158 patent refers to transceivers as modems. *Id.* (citing Ex. 1009, 23; Ex. 1001, 1:42, 3:30–53).

Patent Owner argues that the term "transceiver" need not be interpreted to render a decision on whether to institute trial. Prelim. Resp. 11. Patent Owner, however, does not submit that Petitioner's proposed interpretation of the term "transceiver" is incorrect. Based on the record before us, at this stage of the proceeding, we adopt Petitioner's interpretation of "transceiver" to include "a device, such as a modem, with a transmitter and receiver."

B. Asserted Obviousness over Shively and Stopler

Petitioner contends that claims 1, 2, 4, 15, 16, and 18 are unpatentable under 35 U.S.C. § 103(a) as obvious over Shively and Stopler. Pet. 11–32. Relying on the testimony of Dr. Jose Tellado, Petitioner explains how the combination of Shively and Stopler allegedly meets all of the claim limitations. *Id.* (citing Ex. 1009).

Shively (Ex. 1011)

Shively discloses discrete multitoned transmission (DMT) of data by digital subscriber loop (DSL) modems and the allocation of bits to the discrete multitones. Ex. 1011, 1:5–8. Bit allocation is performed to optimize throughput within aggregate power and power spectral density

mask limits. *Id.* at 4:17–19. The system includes a transmitting modem and a receiving modem connected by a cable having four twisted pairs of conductors. *Id.* at 9:63–65. The modems include a source encoder, a channel decoder, and a digital modulator to take in and transmit data from a data source. *Id.* at 10:9–12. The modems also include a digital demodulator, a channel decoder, and a source decoder to receive the data and supply it to a data sink. *Id.* at 10:12–14. The source encoder compresses data, applies the compressed data to the channel decoder, which performs error correction. *Id.* at 10:15–19. The error corrected data is applied to the digital modulator, which acts as the interface with the communication channel. *Id.* at 10:15–22. The digital demodulator constructs a data stream from the modulated signal and applies it to the channel decoder, which performs error correction, and then applies the corrected data to the source decoder, which decompresses the data. *Id.* at 10:22–26.

In the QAM multitoned modulation, the spectrum is broken into multiple sub-bands or QAM channels. *Id.* at 10:27–29. The digital modulator generates N QAM signal tones, one for each QAM channel. *Id.* at 10:29–30. The serial stream is segmented in to N frames, each having allocated to it k_i bits of data. *Id.* at 10:30–31. The multi-carrier modulator generates N QAM tones, one for each channel, at the same symbol rate but with a respective constellation for each channel. *Id.* at 10:35–37.

Stopler (Ex. 1012)

Stopler discloses a method and apparatus for encoding/framing a data stream of multitoned modulated signals to improve impulse burst immunity. Ex. 1012, 1:8–11. The encoding/framing scheme allows efficient operation

in multipoint to point channels affected by ingress and impulsive interference. *Id.* at 5:11–14. Two dimensional interleaving is performed, with one dimension being time and the other dimension being frequency (tones or sub-channels). *Id.* at 5:18–20. Stopler further discloses a diagonalization scheme, where data packets are spread over time in a diagonal fashion, such that an impulse noise affects more than one user's packets, with the effect on each being reduced. *Id.* at 5:64–67.

Analysis

Claim 1 recites "[i]n a multicarrier modulation system including a first transceiver in communication with a second transceiver." Petitioner contends, for example, that Shively's description of two communicating modems meets the first and second transceivers. Pet. 17. Petitioner further contends that Shively describes a multicarrier modulation system. Pet. 17 (citing Ex. 1011, 1:5–7, 1:35–38).

Claim 1 further recites "using a transmission signal having a plurality of carrier signals for modulating a plurality of data bits." Petitioner contends, for example, that Shively describes a transmitting modem that receives digital data from a data source and modulates separate carriers to represent the digital data, which results in a modulated signal sent to a receiving modem. Pet. 19 (citing Ex. 1011, 5:22–26). Petitioner further contends that Shively explains that the available frequency spectrum is divided into multiple QAM channels, which a person of ordinary skill in the art would have understood to be a "plurality of carrier signals for modulating a plurality of data bits." *See* Pet. 19; Ex. 1009, 36.

Claim 1 recites "each carrier signal having a phase characteristic associated with at least one bit of the plurality of data bits." Petitioner

contends that Shively describes that quadrature amplitude modulation (QAM), for example, produces a signal whose phase and amplitude convey the encoded k-bits of information and that a person having ordinary skill in the art would have understood that the phase of a signal used in QAM to convey bits is a phase characteristic as claimed. Pet. 20; Ex. 1011, 1:29–30; Ex. 1009, 38.

Claim 1 further recites a "method for scrambling the phase characteristics of the carrier signals." Petitioner contends that Stopler describes a phase scrambler that applies a phase scrambling sequence to data in the form of m-tuples which are to be mapped into QAM symbols. Pet. 22; Ex. 1012, 12:20–28. Petitioner contends that the QAM symbols are then provided to a modulator which implements the particular signal modulation. Pet. 22; Ex. 1012, 12:55–57, Fig. 5; Ex. 1009, 39–40. Petitioner explains, with supporting evidence, that it would have been obvious to a person having ordinary skill in the art that modulating the phase-scrambled QAM symbols results in the phases of the carrier signals being scrambled. Pet. 22; Ex. 1009, 44. Petitioner contends that it would have been obvious to a person having ordinary skill in the art to employ Stopler's phase scrambling techniques in Shively's transmitter. Pet. 22; Ex. 1009, 45.

Claim 1 also recites "transmitting the plurality of data bits from the first transceiver to the second transceiver." Petitioner relies on Shively's description of a transmitting modem that transmits data bits to a receiving modem to meet this limitation. Pet. 23. Claim 1 also recites "associating a carrier signal with a value determined independently of any bit of the plurality of data bits carried by the carrier signal, the value associated with the carrier signal determined by a pseudo-random number generator."

Petitioner relies on Stopler to meet this limitation. In particular, Petitioner contends that Stopler teaches a pseudo random generator that outputs consecutive output pairs that are converted into numbers 2a+b. Pet. 24; Ex. 1012, 12:28–45. The value (2a+b), derived from the pseudo-random number generator, Petitioner contends, is a "value determined independently of any bit of the plurality of data bits carried by the carrier signal." Pet. 24; Ex. 1009, 48. Petitioner further explains, with supporting evidence, that because Stopler teaches that the value (2a+b) is associated with a symbol that is transmitted on a sub-channel having a carrier frequency, the value (2a+b) is associated with a carrier signal. Pet 25; Ex. 1009, 48–49.

Claim 1 recites "determining a phase shift for the carrier signal at least based on the value associated with the carrier signal." Petitioner contends that Stopler teaches that the (2a+b) value is used to determine a phase shift because the sum (2a+b) is used to select the amount of rotation to be applied to the symbol, where the phase rotation can be 0, $\pi/2$, π, or $-\pi/2$. Pet. 25; Ex. 1012, 12:28–45; Ex. 1009, 49. Petitioner contends that a person having ordinary skill in the art would have understood that applying a rotation to the symbol results in a phase shift in the carrier signal after the symbol is modulated onto the carrier. Pet. 25–26; Ex. 1009, 49.

Claim 1 recites "modulating at least one bit of the plurality of data bits on the carrier signal" and "modulating the at least one bit on a second carrier signal of the plurality of carrier signals." Petitioner points to descriptions in Shively that describes determining "a respective carrier modulated to transmit one bit in each of a plurality of multitone subchannels of the channel" and "modulating a first set of respective carriers to represent respective unique portions of the data stream." Pet. 26 (quoting Ex. 1011,

8:3–6, 8:5–13). Petitioner further contends that Shively employs QAM multitone modulation, and Shively's multiple sub-bands or QAM channels correspond to the claimed "plurality of carrier signals." Pet. 26; Ex. 1009, 51. Petitioner submits that Stopler also teaches using QAM to convey data bits on carrier signals. Pet. 26–27. Petitioner explains that it would have been obvious to a person with ordinary skill in the art to employ the techniques of Shively and Stopler to modulate at least one bit of the plurality of data bits on the carrier signal. *Id.* at 27 (citing Ex. 1009, 52). Petitioner further argues that Shively discloses modulating a portion of data on multiple carriers, and, therefore, meets the "second carrier" claim limitation. *Id.* at 27–29.

Petitioner provides reasonable rationale for combining Shively and Stopler. Pet. 14–24. For example, Petitioner argues that "[i]t would have been obvious for a POSITA to combine Shively and Stopler because the combination is merely a use of a known technique to improve a similar device, method or product in the same way." *Id.* at 14 (citing Ex. 1009, 27). Petitioner explains that a person of ordinary skill in the art would have recognized that "by transmitting redundant data on multiple carriers, Shively's transmitter would suffer from an increased peak-to-average power ratio" because "the overall transmitted signal in a multicarrier system is essentially the sum of its multiple subcarriers." *Id.* (citing Ex. 1009, 27). Petitioner asserts that a person of ordinary skill in the art "would have sought out an approach to reduce the [(peak-to-average power ratio)] PAR of Shively's transmitter" and "Stopler provides a solution for reducing the PAR of a multicarrier transmitter." *Id.* at 15 (citing Ex. 1009, 29). Petitioner argues that Stopler discloses "a phase scrambler [that] can be employed to

randomize the phase of the individual subcarriers" (*Id.* at 15 (quoting Ex. 1012, 12:24–28)) and "[a] POSITA would have recognized that by randomizing the phase of each subcarrier, Stopler provides a technique that allows two subcarriers in Shively's system to transmit the same bits, but without those two subcarriers having the same phase." *Id.* at 15. Petitioner explains that "[s]ince the two subcarriers are out-of-phase with one another, the subcarriers will not reach their peak power at the same time," thereby reducing the peak-to-average power ratio (PAR) in Shively's system. *Id.* Accordingly, Petitioner argues that "[c]ombining Stopler's phase scrambler into Shively's transmitter would have been a relatively simple and obvious solution to reduce Shively's PAR." *Id.* at 16 (citing Ex. 1009, 29).

Independent claim 15 is similar to claim 1. Petitioner has made a showing with respect to claim 15 similar to its showing with respect to claim 1. *See, e.g.*, Pet. 30–32. To the extent that claim 15 is different from claim 1, Petitioner has accounted for such differences. We also have reviewed Petitioner's showing with respect to dependent claims 2, 4, 16, and 18. Based on the current record before us, and notwithstanding Patent Owner's arguments, which we address below, we determine that there is a reasonable likelihood that Petitioner would prevail in establishing that claims 1, 2, 4, 15, 16, and 18 would have been obvious over Shively and Stopler.

Patent Owner's Contentions

Patent Owner argues that "no review should be instituted because Petitioner has not provided a sufficient rationale to combine Shively and Stopler." Prelim. Resp. 13. Specifically, Patent Owner argues (1) Shively does not suffer from an increased peak-to-average power ratio (PAR), (2) Shively only uses a small number of carriers and therefore would not

suffer from a PAR problem, (3) Stopler is ambiguous as to what it teaches, and (4) Petitioner's rationale for combining Shively and Stopler suffers from hindsight bias. *Id.* at 13–21.

We are not persuaded by Patent Owner's attorney arguments because such arguments do not persuade us that Petitioner's challenge, which is based on record evidence is insufficient to institute a trial. For example, Petitioner explains, through the testimony of Dr. Tellado, that a person with ordinary skill in the art would have recognized that the combination of Shively and Stopler is nothing more than the use of a known technique to improve a similar device, method or product. Pet. 14 (citing Ex. 1009, 27). Dr. Tellado further explains why a person with ordinary skill in the art would have recognized that Shively would have suffered from increased PAR. Ex. 1009, 27. Patent Owner's attorney arguments regarding Shively's lack of increased PAR and Stopler's ambiguity are not persuasive because they are not based on evidence of record, such as from a declarant attesting to how a person of ordinary skill in the art would have understood the teachings of Stopler and Shively. Furthermore, Dr. Tellado discloses that the knowledge of the advantages and benefits of the combination were known at the time of the invention, and, accordingly, we are not persuaded that Petitioner's rationale for combining Shively and Stopler is based on impermissible hindsight. *See* Pet. 14–16; Ex. 1009, 27–30.

C. Asserted Obviousness over Shively, Stopler, and Gerszberg

Petitioner contends that claims 3, 5, 14, 17, 19, and 28–30 are unpatentable under 35 U.S.C. § 103(a) as obvious over Shively, Stopler, and Gerszberg. Pet. 33–41. Relying on the testimony of Dr. Jose Tellado,

Petitioner explains how the combination of Shively, Stopler, and Gerszberg allegedly meets all of the claim limitations. *Id.* (citing Ex. 1009).

Gerszberg discloses using a Digital Subscriber Line (DSL) modem, such as an ADSL modem, to transmit and receive modulated data. Ex. 1013, 11:66–12:7. The modem uses DMT modulation to transmit data. *Id.* at 12:7–9. Gerszberg further describes types of data services that may be provided to subscriber premises by a DSL modem that uses DMT modulation, such as high-speed internet access and video services. *Id.* at 7:44–60, 8:16–36, 10:63–11:3. Gerszberg also describes that a DSL modem can be used in various DSL communications, such as HDSL, ADSL, SDSL, and VDSL. *Id.* at 9:66–10:3.

Based on the record before us, Petitioner has accounted sufficiently for dependent claims 3, 5, 14, 17, 19, and 28–30. Pet. 33–41. For example, claim 3 depends from claim 1 and recites "wherein one or more of the first transceiver and second transceiver are VDSL transceivers." Claim 17, which depends from independent claim 15, is similar to claim 3. Petitioner relies on Gerszberg's description that its "DSL modem may be constructed using any of the techniques described in the applications incorporated by reference below" such as "High Speed Digital Subscriber Line (HDSL), Asymmetric Digital Subscriber Line (ADSL), Symmetrical Digital Subscriber Line (SDSL) and Very high data rate Digital Subscriber Line (VDSL)." Pet. 37–38 (emphasis omitted); Ex. 1013, 9:62–10:3. Petitioner contends that it would have been obvious to replace Shively's ADSL modems with VDSL modems, as taught by Gerszberg, in order to achieve higher bandwidth. Pet. 38; Ex. 1009, 67. Moreover, Petitioner provides a

rational reason for combining Gerszberg with the combined teachings of Shively and Stopler. Pet. 34–37.

We have reviewed Petitioner's showing with respect to all of claims 3, 5, 14, 17, 19, and 28–30 and determine that there is reasonable likelihood that Petitioner would prevail in its challenge to those claims. Patent Owner does not present arguments for any of those claims separate from the arguments addressed previously.

D. Asserted Obviousness over Shively, Stopler, and Bremer

Petitioner contends that claims 6, 9, 10, 12, 20, 23, 24, and 26 are unpatentable under 35 U.S.C. § 103(a) as obvious over Shively, Stopler, and Bremer. Pet. 41–50. Relying on the testimony of Dr. Jose Tellado, Petitioner explains how the combination of Shively, Stopler, and Bremer allegedly meets all of the claim limitations. *Id*. (citing Ex. 1009).

Bremer relates to encoding and decoding techniques for a data signal that is transmitted over a communications channel. Ex. 1017, 1:41–67. Bremer describes using a pseudorandom generator to encode the gain or phase of a signal prior to transmission, and on the receiving end, uses a second pseudorandom generator to decode the encoded data signal. *Id*. at 1:53–64.

Based on the record before us, Petitioner has accounted sufficiently for dependent claims 6, 9, 10, 12, 20, 23, 24, and 26. Pet. 41–50. For example, claim 6 depends from claim 1 and recites "independently deriving the values associated with each carrier using a second pseudo-random number generator in the second transceiver." Claim 20, which depends from independent claim 15, is similar to claim 6. Petitioner contends that Bremer teaches that when a transmitting device includes components causing a

pseudorandom phase shift to the transmitted signal, a receiving device requires complementary components to decode the signal. Pet. 45; Ex. 1017, 1:60–65. Petitioner further contends that Bremer describes altering gain and phase modifiers of a data signal being transmitted from a QAM modem based on values from a pseudorandom signal generator, which generates a pseudorandom number. Pet. 45; Ex. 1017, Abstract, 2:32; Ex. 1009, 77. Petitioner further contends that the values produced by a second pseudorandom number generator are independent of the values produced by a first pseudorandom number generator. Pet. 46; Ex. 1017, 4:10–16, 4:35–36; Ex. 1009, 80. Petitioner provides rational reasoning for combining Bremer with the combined teachings of Shively and Stopler. Pet. 42–44.

We have reviewed Petitioner's showing with respect to all of claims 6, 9, 10, 12, 20, 23, 24, and 26 and determine that there is reasonable likelihood that Petitioner would prevail in its challenge to those claims. Patent Owner does not present arguments for any of those claims separate from the arguments addressed previously.

E. Asserted Obviousness over Shively, Stopler, Bremer, and Gerszberg

Petitioner contends that claims 8, 11, 13, 22, 25, and 27 are unpatentable under 35 U.S.C. § 103(a) as obvious over Shively, Stopler, Bremer, and Gerszberg. Pet. 50–53. Relying on the testimony of Dr. Jose Tellado, Petitioner explains how the combination of Shively, Stopler, Bremer, and Gerszberg allegedly meets all of the claim limitations. *Id.* (citing Ex. 1009).

Based on the record before us, Petitioner has accounted sufficiently for dependent claims 8, 11, 13, 22, 25, and 27. Pet. 50–53. For example,

claim 11 depends from claim 6, and recites "wherein the first and second transceivers are VDSL transceivers." Claim 25, which depends from claim 20, is similar to claim 11. Petitioner relies on Gerszberg's description that its "DSL modem may be constructed using any of the techniques described in the applications incorporated by reference below" such as "High Speed Digital Subscriber Line (HDSL), Asymmetric Digital Subscriber Line (ADSL), Symmetrical Digital Subscriber Line (SDSL) and Very high data rate Digital Subscriber Line (VDSL)." Pet. 37–38 (emphasis omitted), 52; Ex. 1013, 9:62–10:3. Petitioner contends that it would have been obvious to replace Shively's ADSL modems with VDSL modems, as taught by Gerszberg, in order to achieve higher bandwidth. Pet. 38, 52; Ex. 1009, 67, 89. Moreover, Petitioner provides a rational reason for combining Gerszberg with the combined teachings of Shively and Stopler. Pet. 50–51.

We have reviewed Petitioner's showing with respect to all of claims 8, 11, 13, 22, 25, and 27 and determine that there is reasonable likelihood that Petitioner would prevail in its challenge to those claims. Patent Owner does not present arguments for any of those claims separate from the arguments addressed previously.

F. Asserted Obviousness over Shively, Stopler, Bremer, and Flammer

Petitioner contends that claims 7 and 21 are unpatentable under 35 U.S.C. § 103(a) as obvious over Shively, Stopler, Bremer, and Flammer. Pet. 53–60. Relying on the testimony of Dr. Jose Tellado, Petitioner explains how the combination of Shively, Stopler, Bremer, and Flammer allegedly meets all of the claim limitations. *Id.* (citing Ex. 1009).

Flammer relates to data transmission between a source node and a target node, where each node has a transmitter and a receiver. Ex. 1019,

Abstract. Flammer uses pseudo-random number generators in its communication system. Flammer describes synchronization between pseudo-random number generators at different ends of a communication channel. *Id.* at 3:49–4:10. As part of the synchronization, an acquisition/ synchronization packet is transmitted that includes a seed value from the source node to the target node. *Id.* at 3:52–58. The transmitted seed value is used to initialize the pseudo-random number generators executing at the respective source and target nodes. *Id.* at 3:52–4:9. Once the pseudo-random number generators at both the source node and the target node have the same seed value, they can generate identical pseudo-random number sequences for selecting frequency bands. *Id.* at 4:42–53.

Based on the record before us, Petitioner has accounted sufficiently for dependent claims 7 and 21. Pet. 50–53. Claim 7 depends from claim 6 and recites "using in the first and second transceivers a same seed for the first and second pseudo-random number generators and the value of the seed is transmitted from the first transceiver to the second transceiver." Claim 21, which depends from claim 20, is similar to claim 7. Petitioner contends that Flammer teaches a transceiver as a node having a transmitter and a receiver. Pet. 57; Ex. 1019, Abstract. Petitioner further contends that in Flammer, the source node is the first transceiver and the target node is the second transceiver. Ex. 1009, 92. Petitioner argues that Flammer teaches that it was known for the pseudo-random number generators in the source node and the target node to use the same seed value. Pet. 57; Ex. 1019, 3:52–67; Ex. 1009, 92–93. Petitioner further explains, with supporting evidence, that Flammer teaches transmitting a value of a seed from a source node (a first transceiver) to a target node (a second transceiver) when the

target node receives an acquisition/synchronization packet which contains information about the node, including a seed value. Moreover, Petitioner provides a rational reason for combining Flammer with the combined teachings of Shively, Stopler, and Bremer. Pet. 54–57.

We have reviewed Petitioner's showing with respect to claims 7 and 21 and determine that there is reasonable likelihood that Petitioner would prevail in its challenge to those claims. Patent Owner does not present arguments for claims 7 and 21 separate from the arguments addressed previously.

III. CONCLUSION

For the foregoing reasons, we determine that the information presented establishes a reasonable likelihood that Petitioner would prevail in showing that claims 1–30 of the '158 patent are unpatentable. At this preliminary stage, we have not made a final determination with respect to the patentability of the challenged claims or any underlying factual and legal issues.

IV. ORDER

Accordingly, it is:

ORDERED that pursuant to 35 U.S.C. § 314(a), an *inter partes* review is hereby instituted for the following grounds of unpatentability:

References	**Basis**	**Claims**
Shively and Stopler	§ 103(a)	1, 2, 4, 15, 16, and 18
Shively, Stopler, and Gerszberg	§ 103(a)	3, 5, 14, 17, 19, and 28–30
Shively, Stopler, and Bremer	§ 103(a)	6, 9, 10, 12, 20, 23, 24, and 26
Shively, Stopler, Bremer, and Gerszberg	§ 103(a)	8, 11, 13, 22, 25, and 27

References	Basis	Claims
Shively, Stopler, Bremer, and Flammer	§ 103(a)	7 and 21

FURTHER ORDERED that no other ground of unpatentability asserted in the Petition is authorized for this *inter partes* review; and

FURTHER ORDERED that pursuant to 35 U.S.C. § 314(c) and 37 C.F.R. § 42.4, notice is hereby given of the institution of a trial; the trial will commence on the entry date of this decision.

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Paper 11
Entered: January 19, 2017

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

DISH NETWORK, LLC,
Petitioner,

v.

TQ DELTA, LLC,
Patent Owner.

Case IPR2017-00255
Patent 8,718,158 B2

Before SALLY C. MEDLEY, KALYAN K. DESHPANDE, and TREVOR M. JEFFERSON, *Administrative Patent Judges*.

MEDLEY, *Administrative Patent Judge*.

DECISION
Institution of *Inter Partes* Review
37 C.F.R. § 42.108

Petitioner's Motion for Joinder
37 C.F.R. § 42.122(b)

I. INTRODUCTION

DISH Network, L.L.C. ("Petitioner" or "Dish") filed a Petition for *inter partes* review of claims 1–30 of U.S. Patent No. 8,718,158 B2 (Ex. 1001, "the '158 patent"). Paper 3 ("Pet."). Concurrently with its Petition, Dish filed a Motion for Joinder with *Cisco Systems, Inc. v. TQ Delta, LLC*, Case IPR2016-01021 ("the Cisco IPR"). Paper 2 ("Mot."). TQ Delta, LLC ("Patent Owner") submits that it does not oppose joinder. *See* Paper 8. Patent Owner also elected to waive its Preliminary Response. *Id*.

For the reasons explained below, we institute an *inter partes* review of claims 1–30 of the '158 patent and grant Dish's Motion for Joinder.

II. RELATED PROCEEDINGS

Petitioner and Patent Owner identify several pending judicial matters as relating to the '158 patent. Pet. 1; Mot. 2–3; Paper 4, 2–3.

In the Cisco IPR, we instituted an *inter partes* review of claims 1–30 of the '158 patent on the following ground:

References	**Basis**	**Claims**
Shively[1] and Stopler[2]	§ 103(a)	1, 2, 4, 15, 16, and 18
Shively, Stopler, and Gerszberg[3]	§ 103(a)	3, 5, 14, 17, 19, and 28–30
Shively, Stopler, and Bremer[4]	§ 103(a)	6, 9, 10, 12, 20, 23, 24, and 26

[1] U.S. Patent No. 6,144,696; issued Nov. 7, 2000 (Ex. 1011) ("Shively").
[2] U.S. Patent No. 6,625,219 B1; issued Sept. 23, 2003 (Ex. 1012) ("Stopler").
[3] U.S. Patent No. 6,424,646 B1; issued July 23, 2002 (Ex. 1013) ("Gerszberg").
[4] U.S. Patent No. 4,924,516; issued May 8, 1990 (Ex. 1017) ("Bremer").

References	Basis	Claims
Shively, Stopler, Bremer, and Gerszberg	§ 103(a)	8, 11, 13, 22, 25, and 27
Shively, Stopler, Bremer, and Flammer[5]	§ 103(a)	7 and 21

Cisco Systems, Inc. v. TQ Delta, LLC, Case IPR2016-01021, slip op. at 20–21 (PTAB Nov. 4, 2016) (Paper 7) ("Cisco Dec.").

III. INSTITUTION OF *INTER PARTES* REVIEW

The Petition in this proceeding asserts the same grounds of unpatentability as the ones on which we instituted review in the Cisco IPR. *Compare* Pet. 12–63, *with* Cisco Dec. 20–21. Indeed, Petitioner contends that the Petition asserts only the grounds that the Board instituted in the Cisco IPR, there are no new arguments for the Board to consider, and Petitioner relies on the same exhibits and expert declaration as the Cisco IPR. Mot. 5.

For the same reasons set forth in our institution decision in the Cisco IPR, we determine that the information presented in Dish's Petition shows a reasonable likelihood that Petitioner would prevail in showing that (a) claims 1, 2, 4, 15, 16, and 18 would have been obvious over Shively and Stopler, (b) claims 3, 5, 14, 17, 19, and 28–30 would have been obvious over Shively, Stopler, and Gerszberg, (c) claims 6, 9, 10, 12, 20, 23, 24, and 26 would have been obvious over Shively, Stopler, and Bremer, (d) claims 8, 11, 13, 22, 25, and 27 would have been obvious over Shively, Stopler, Bremer, and Gerszberg, and (e) claims 7 and 21 would have been obvious over Shively, Stopler, Bremer, and Flammer. *See* Cisco Dec. 7–20.

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[5] U.S. Patent No. 5,515,369; issued May 7, 1996 (Ex. 1019) ("Flammer").

Accordingly, we institute an *inter partes* review on the same grounds as the ones on which we instituted review in the Cisco IPR. We do not institute *inter partes* review on any other grounds.

IV. GRANT OF MOTION FOR JOINDER

The Petition and Motion for Joinder in this proceeding were accorded a filing date of November 11, 2016. *See* Paper 7. Thus, Petitioner's Motion for Joinder is timely because joinder was requested no later than one month after the institution date of the Cisco IPR, i.e., November 4, 2016. *See* 37 C.F.R. § 42.122(b).

The statutory provision governing joinder in *inter partes* review proceedings is 35 U.S.C. § 315(c), which reads:

> If the Director institutes an inter partes review, the Director, in his or her discretion, may join as a party to that inter partes review any person who properly files a petition under section 311 that the Director, after receiving a preliminary response under section 313 or the expiration of the time for filing such a response, determines warrants the institution of an *inter partes* review under section 314.

A motion for joinder should (1) set forth reasons why joinder is appropriate; (2) identify any new grounds of unpatentability asserted in the petition; (3) explain what impact (if any) joinder would have on the trial schedule for the existing review; and (4) address specifically how briefing and discovery may be simplified. *See Kyocera Corp. v. Softview LLC*, Case IPR2013-00004, slip op. at 4 (PTAB Apr. 24, 2013) (Paper 15).

As noted, the Petition in this case asserts the same unpatentability grounds on which we instituted review in the Cisco IPR. *See* Mot. 5. Dish also relies on the same prior art analysis and expert testimony submitted by the Cisco Petitioners. *See id.* Indeed, the Petition is nearly identical to the

petition filed by the Cisco Petitioners with respect to the grounds on which review was instituted in the Cisco IPR. *See id.* Thus, this *inter partes* review does not present any ground or matter not already at issue in the Cisco IPR.

If joinder is granted, Dish anticipates participating in the proceeding in a limited capacity absent termination of Cisco Petitioner as a party. *Id.* at 6. Dish agrees to "assume a limited 'understudy' role" and "would only take on an active role if Cisco were no longer a party to the IPR." Dish further represents that it "presents no new grounds for invalidity and its presence in the proceedings will not introduce any additional arguments, briefing or need for discovery." *Id.* Because Dish expects to participate only in a limited capacity, Dish submits that joinder will not impact the trial schedule for the Cisco IPR. *Id.* at 5–6.

We agree with Petitioner that joinder with the Cisco IPR is appropriate under the circumstances. Accordingly, we *grant* Petitioner's Motion for Joinder.

V. ORDER

Accordingly, it is:

ORDERED that an *inter partes* review is instituted in IPR2017-00255;

FURTHER ORDERED that the Motion for Joinder with IPR2016-01021 is *granted*, and DISH Network, L.L.C. is joined as a petitioner in IPR2016-01021;

FURTHER ORDERED that IPR2017-00255 is terminated under 37 C.F.R. § 42.72, and all further filings shall be made only in IPR2016-01021;

FURTHER ORDERED that, subsequent to joinder, the grounds for trial in IPR2016-01021 remain unchanged;

FURTHER ORDERED that, subsequent to joinder, the Scheduling Order in place for IPR2016-01021 (Paper 8) remains unchanged;

FURTHER ORDERED that in IPR2016-01021, the Cisco Petitioner and Dish will file each paper, except for a motion that does not involve the other party, as a single, consolidated filing, subject to the page limits set forth in 37 C.F.R. § 42.24, and shall identify each such filing as a consolidated filing;

FURTHER ORDERED that for any consolidated filing, if Dish wishes to file an additional paper to address points of disagreement with the Cisco Petitioner, Dish must request authorization from the Board to file a motion for additional pages, and no additional paper may be filed unless the Board grants such a motion;

FURTHER ORDERED that the Cisco Petitioner and Dish shall collectively designate attorneys to conduct the cross-examination of any witness produced by Patent Owner and the redirect of any witness produced by the Cisco Petitioner and Dish, within the timeframes set forth in 37 C.F.R. § 42.53(c) or agreed to by the parties;

FURTHER ORDERED that the Cisco Petitioner and Dish shall collectively designate attorneys to present at the oral hearing, if requested and scheduled, in a consolidated argument;

FURTHER ORDERED that the case caption in IPR2016-01021 shall be changed to reflect joinder of Dish as a petitioner in accordance with the attached example; and

FURTHER ORDERED that a copy of this Decision shall be entered into the record of IPR2016-01021.

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UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CISCO SYSTEMS, INC. and DISH NETWORK, LLC,
Petitioner,

v.

TQ DELTA, LLC,
Patent Owner.

Case IPR2016-01021[1]
Patent 8,718,158 B2

[1] DISH Network, L.L.C., who filed a Petition in IPR2017-00255, has been joined as a petitioner in this proceeding.

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UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CISCO SYSTEMS, INC. and DISH NETWORK, LLC
Petitioners

v.

TQ DELTA, LLC
Patent Owner

Case No. IPR2016-01021[1]
Patent No. 8,718,158

PATENT OWNER RESPONSE UNDER 37 CFR § 42.120

[1] DISH Network, L.L.C., who filed a Petition in IPR2017-00255, has been joined as a petitioner in this proceeding.

TABLE OF CONTENTS

I. INTRODUCTION

Patent Owner TQ Delta, LLC submits this Patent Owner Response under 37 CFR § 42.120 to the Petition filed by Cisco, Inc. requesting *inter partes* review for claims 1–30 of U.S. Pat. No. 8,718,158 ("the '158 patent").

The Board instituted *inter partes* review on five grounds:

1. whether claims 1, 2, 4, 15, 16, and 18 of the '158 patent are unpatentable under 35 U.S.C. § 103(a) over U.S. Pat. No. 6,144,696 ("Shively") and U.S. Pat. No. 6,625,219 ("Stopler");

2. whether claims 3, 5, 14, 17, 19, and 20–30 of the '158 patent are unpatentable under 35 U.S.C. § 103(a) over Shively, Stopler, and U.S. Pat. No. 6,424,646 ("Gerszberg");

3. whether claims 6, 9, 10, 12, 20, 23, 24, and 26 of the '158 patent are unpatentable under 35 U.S.C. § 103(a) over Shively, Stopler, and U.S. Pat. No. 4,924,516 ("Bremer");

4. whether claims 8, 11, 13, 22, 25, and 27 of the '158 patent are unpatentable under 35 U.S.C. § 103(a) over Shively, Stopler, Bremer, and Gerszberg; and

5. whether claims 7 and 21 of the '158 patent are unpatentable under 35 U.S.C. § 103(a) over Shively, Stopler, Bremer, and U.S. Pat. No. 5,515,369 ("Flammer").

After institution, additional parties—including: Dish Network, LLC; Comcast Cable Communications, LLC; Cox Communications, Inc.; Time Warner

Cable Enterprises LLC; Verizon Services Corp.; and ARRIS Group, Inc.—filed petitions that are identical in all substantive respects to the Cisco Petition. *See* IPR2017-00255 and IPR2017-00417. These additional parties moved to join as petitioners, and collectively with Cisco, are referred to herein as "Petitioners." For brevity, this Patent Owner response will cite only to the Cisco Petition and its corresponding exhibits.

In the Institution Decision, the Board did not reach the merits of Patent Owner's arguments in the Patent Owner Preliminary Response, but rather characterized them as "attorney argument" and accepted Petitioners' expert declarant's testimony as true because Patent Owner did not support it's argument with expert testimony. This Patent Owner Response is fully supported by the cited evidence, including the declaration of Dr. Robert T. Short.

The Petition fails to prove, by a preponderance of the evidence, that any claim of the '158 patent is unpatentable because there is no credible or accurate evidence demonstrating why one having ordinary skill in the art would have combined Shively and Stopler. Petitioners' rationale for the combination fundamentally relies on the contention that Shively suffers from a problem (*i.e.*, a problem with its "peak-to-average power ratio" or "PAR") that Stopler solves the purported problem by performing "phase scrambling." But, Shively does not have a PAR problem so there would have been no motivation to look for a solution.

Additionally, with respect to claims 1–15, Stopler does not disclose phase scrambling as recited. Furthermore, for claims 6–13, 20–28, and 30, Petitioners have not asserted a legally recognizable reason for combining Bremer with Stopler or Shively. Instead of satisfying their burden, Petitioners misunderstand the teachings of these references, make unsupported assumptions having no basis in fact, and, ultimately rely on only hindsight bias to cobble together the references.

As such, Petitioners' grounds for alleged obviousness fail. Patent Owner respectfully requests that the Board issue a Final Written Decision finding that Petitioners did not meet their burden to prove unpatentability of claims 1–30 of the '158 patent.

II. INTRODUCTION TO TECHNOLOGICAL CONCEPTS

In order to understand the issues at hand in this IPR, it is first necessary to be able to answer the following questions:

1) What is a multicarrier system?

2) What is peak-to-average power ratio, or "PAR"?

3) Under what conditions does a PAR "problem" occur?

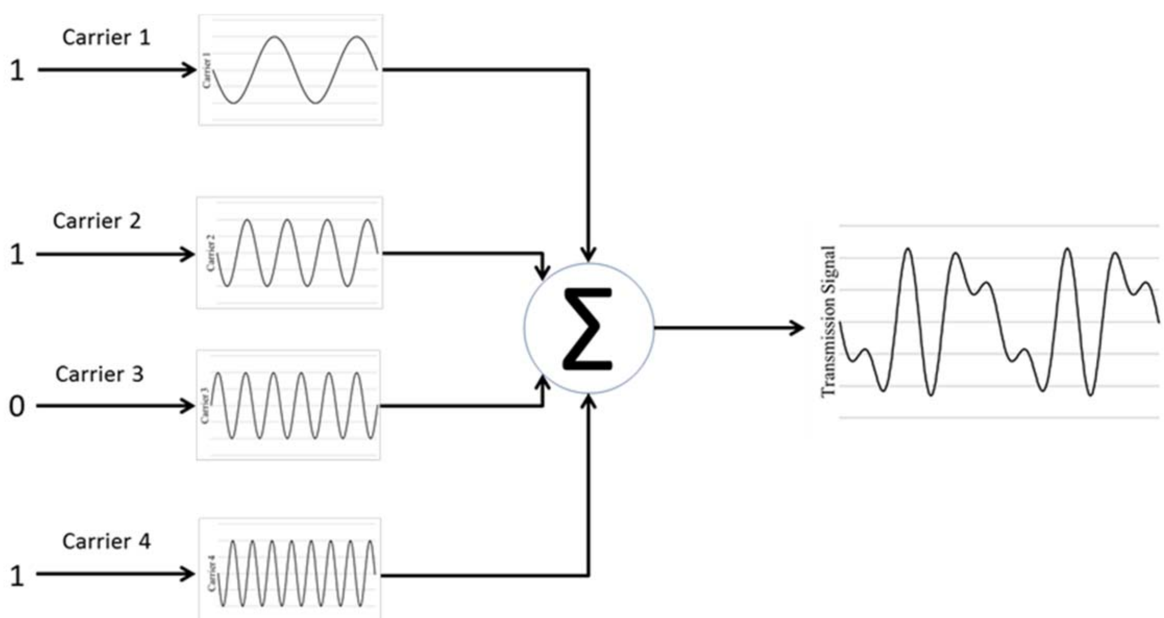
4) How are the terms "symbol" and "carrier" used in this Patent Owner Response and accompanying declaration?

This introduction answers these questions.

A. Multicarrier Systems

The '158 patent discloses a system that communicates using multicarrier signals. Ex. 1001 at 1:28–31. A multicarrier signal includes a number of carrier signals (or carriers) each operating at a different frequency. Each carrier is modulated to encode one or more bits (*i.e.*, "1" or "0"). Each carrier effectively serves as a separate sub-channel for carrying data. The carriers are combined as a group to produce a transmission signal, which is transmitted across a transmission medium (*e.g.*, phone lines, coaxial cable, the air, *etc.*) to a receiver. *See* Ex. 2003 at ¶ 17.

In an example illustrated below, four carriers—Carrier 1, Carrier 2, Carrier 3, and Carrier 4—are combined simultaneously into one transmission signal.



See Ex. 2003 at ¶ 18.

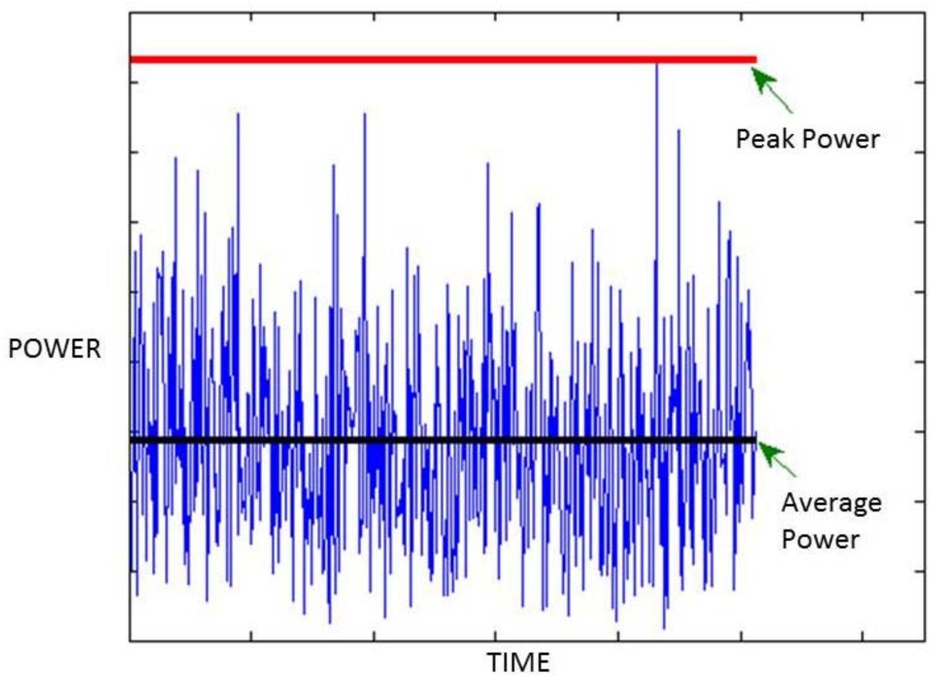
Multicarrier systems may use the phase of carriers to encode different bit values. In the example illustrated above, a carrier with a phase of zero represents a bit value of "0"; conversely, a carrier with a phase-shift of π (or 180°) represents a bit value of "1". In this example, Carriers 1, 2, and 4 have a phase-shift of π, and therefore each represent a "1". Carrier 3 has as phase of zero, and therefore represents a "0". Together, these four carriers encode input bits having binary values of 1, 1, 0, and 1. This information is transmitted as a single transmission signal—that is, the irregular waveform shown above on the right side of the figure. In practice, a multicarrier transmission signal will typically comprise a combination of many more than four carriers (*e.g.*, hundreds or even thousands of carriers) and in this way can substantially increase the "speed" or data carrying capacity of the system. *See* Ex. 2003 at ¶ 19.

B. Peak-to-Average Power Ratio ("PAR")

A multicarrier transmission signal can be characterized by a metric known as "PAR," which stands for peak-to-average ratio or peak-to-average power ratio. Ex. 1001 at 1:64–2:4. As the '158 patent explains, "The PAR of a transmission signal is the ratio of the instantaneous peak value (*i.e.*, maximum magnitude) of a signal parameter (*e.g.*, voltage, current, phase, frequency, ***power***) to the time-average value of the signal parameter." *Id.* at 1:67–2:4 (emphasis added). References to PAR herein relate to PAR for the power of a transmission signal. *See* Ex. 2003 at

¶ 20.

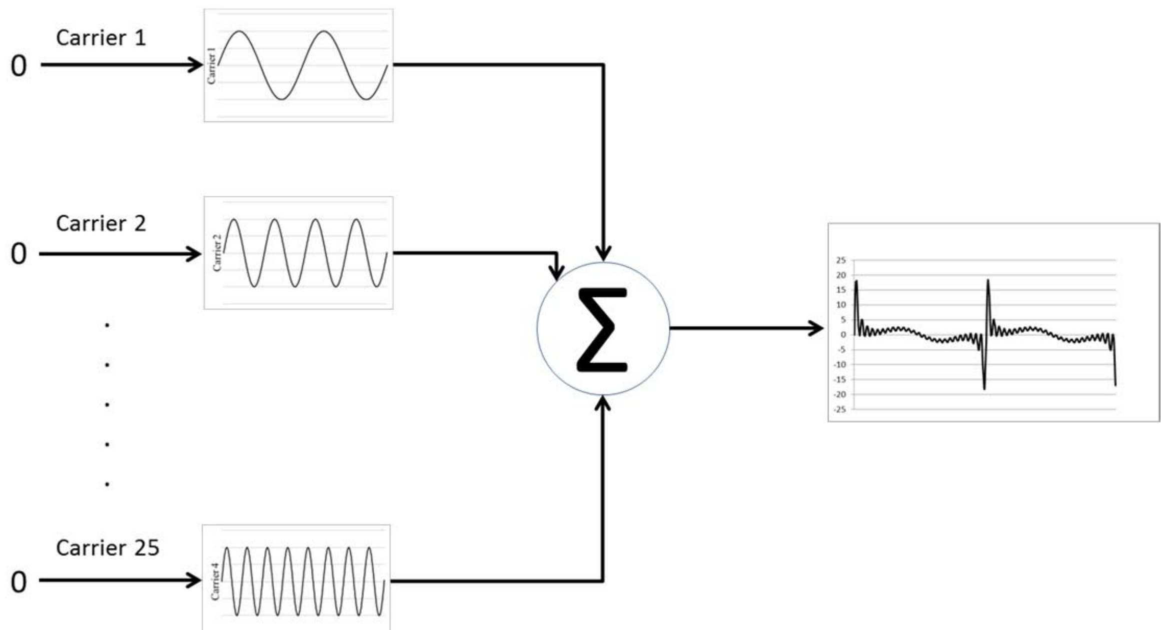
One of the central issues in this IPR relates to PAR. In the following illustration, a signal (blue) has a peak power (red line) and an average power (black line). The ratio of the peak power to the average power of the signal is the PAR.



See Ex. 2003 at ¶ 21.

A high PAR can occur when a large number (or percentage) of the carriers have the same phase. The '158 patent recognized that: "If the phase of the modulated carriers [in a transmission signal] is not random, then the PAR can increase greatly." Ex. 1001 at 2:17–18. The phases of the carriers would not be "random," for example, when the underlying data being modulated is repetitive (*e.g.*, a long string of 0s or a long string of 1s), or where the same bit or bits is/are

purposely sent in a redundant manner on multiple carriers. In the example below, all 25 of the carriers have the same phase of zero (which would be the case if the same bit or bits was/were sent on every carrier). Because the carrier signals are "in-phase," their amplitudes will add together to create a transmission signal (illustrated on the right side of the figure below) having large spikes in amplitude and, therefore, a high PAR.



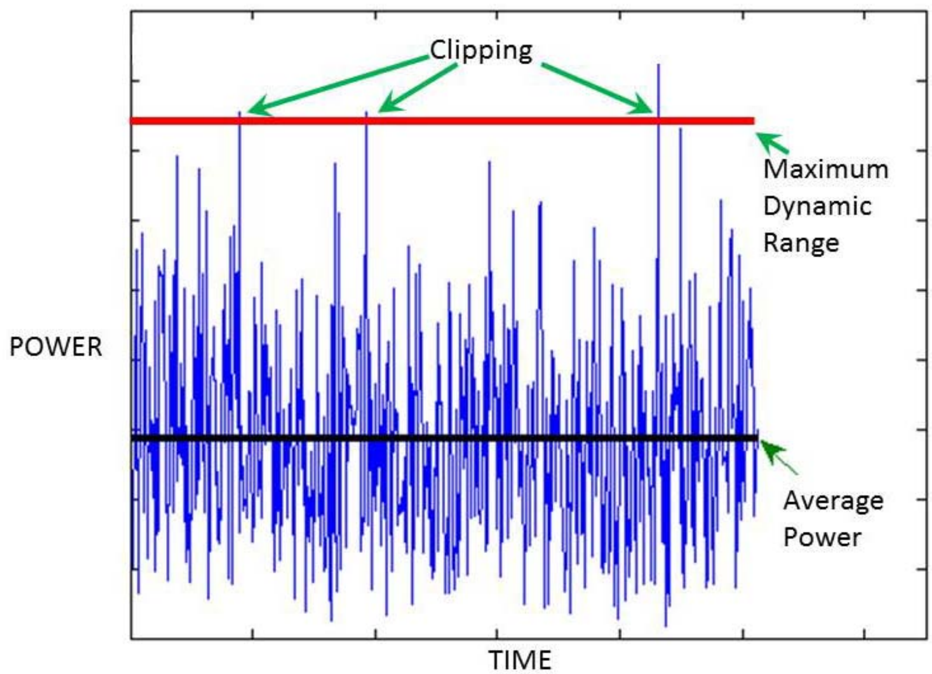
See Ex. 2003 at ¶ 22.

C. PAR "Problem"

Because a multicarrier transmission signal is the sum of many carrier signals, the transmission signal is expected to have a significant PAR. Conventional multicarrier systems, therefore, were designed to accommodate a degree PAR. There is only a PAR "problem," however, when an undue amount of

PAR-induced errors occur in a multicarrier transmitter. *See* Ex. 2003 at ¶ 23.

Electronic components in a multicarrier transceiver are ideally designed to process multicarrier signals without distortion. Distortion occurs when a signal exceeds the capacity (or dynamic range) of an electronic component, such as an amplifier, a digital-to-analog converter, or an analog-to-digital converter. When the maximum dynamic range of a component is exceeded, the signal will become distorted or will "clip."



See Ex. 2003 at ¶ 24.

As a result of clipping, the portion of the signal exceeding the component's dynamic range is truncated and the information in the cut off signal portion is lost. *See* Ex. 2003 at ¶ 25.

One way to reduce the probability of clipping is to use transceiver components with larger dynamic ranges. Such components, however, can be expensive and may consume a relatively large amount of power. Increasing the dynamic ranges of the components to eliminate any possibility of clipping, therefore, can be impractical. *See* Ex. 2003 at ¶ 26.

Instead of demanding ideal circuitry, multicarrier systems are designed to actually allow a certain amount of clipping. This design criterion is specified as a "clipping rate." One such multicarrier system is digital subscriber line ("DSL").[2] In DSL at the time of the invention (referred to herein as "ADSL-1995") the maximum allowable clipping rate is one in every 10^7 (ten million) samples, which corresponds to a clipping probability of 10^{-7} (or one in ten million). Ex. 1018 at p. 64, § 6.11.1. This exact clipping probability is also referenced in the '158 patent.

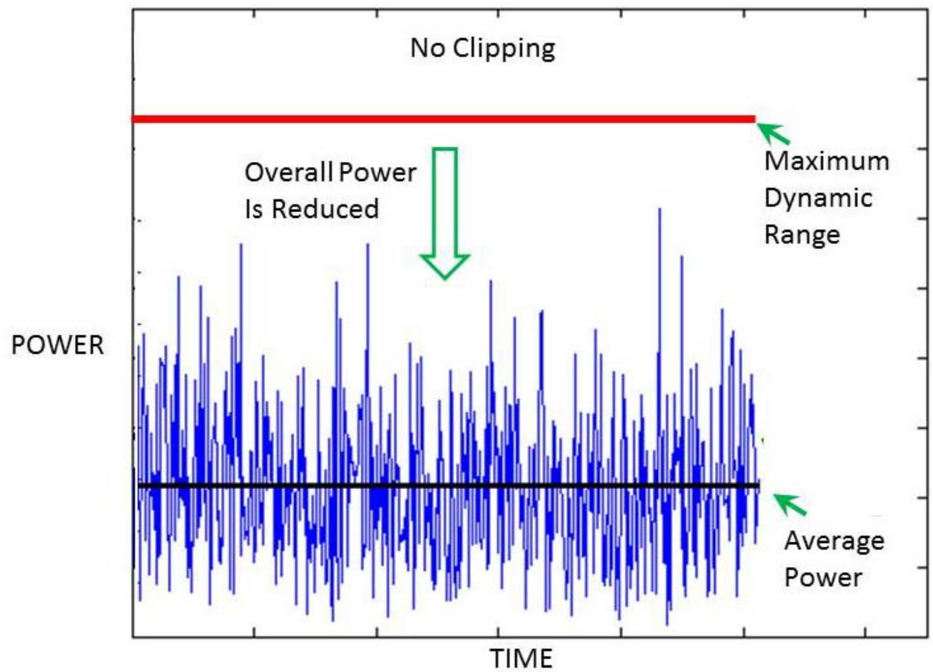
[2] This is an apt example, as DSL is the subject technology of a preferred embodiment in the '158 patent (Ex. 1001 at 3:27–28), Shively (Ex. 1011 at 1:4–5), Stopler (Ex. 1012 at 12: 23–24), and Gerszberg (Ex. 1013 at 1:19–26). A particular DSL standard in use at the time of the invention is defined in Petitioners' Exhibit 1018—ANSI standard T1.413-1995 ("ADSL-1995"). The ADSL-1995 standard is described in Shively (Ex. 1011 at 1:51–53 and 2:12–24) and is discussed in the Petition at p. 37. *See* Ex. 2003 at ¶ 28.

See Ex. 1001 at 2:8–10. *See* Ex. 2003 at ¶ 27.

In ADSL-1995, the ideal sampling rate is approximately 2.2 million samples/second. Given this sampling rate and a clipping probability of 10^{-7}, there would be a clipping error when processing a transmission signal about once every 4.55 seconds on average. This clipping rate is deemed acceptable because, at this rate, error correction methods are capable of fixing the errors cause by clipping. *See* Ex. 2003 at ¶ 29.

A PAR "problem" exists when the probability of clipping or average clipping rate exceeds the maximum allowable rate. In the example above, if there is a clipping error once every 3 seconds (on average), then a PAR problem exists—because the rate of clipping is unacceptably high since 3 seconds is less than 4.55 seconds. As the inventor of the '158 patent recognized, "If the phase of the modulated carriers is not random, then the PAR can increase greatly." Ex. 1001 at 2:17–18. "An increased PAR can result in a system with high power consumption and/or with ***high probability of clipping the transmission signal***." *Id.* at 2:27–29 (emphasis added). Contrarily, if probability of clipping or average clipping rate does not increase above the acceptable rate of the system (*e.g.*, 10^{-7} or once every 4.55 seconds on average in ADSL-1995), then there is no PAR problem. *See* Ex. 2003 at ¶ 30.

One way to decrease the impact of PAR and reduce the probability of clipping is by reducing the overall signal power below the maximum overall signal power for which the system was designed, as depicted below.



See Ex. 2003 at ¶ 31.

As discussed below in § IV.A, the system disclosed in Shively is an example of a system in which the overall signal power is reduced below the maximum overall signal power for which the system was designed. Such power reduction is shown by Shively, and it results in a system with virtually no clipping at all. *See* Ex. 2003 at ¶ 32.

D. A Note On Terminology

There is some overlap and apparent inconsistency with certain terminology

used by Petitioners and the references of record. Particularly confusing is the use of "symbol." Generally, "symbol" can have two meanings. First, "symbol" can refer to information transmitted on one carrier during a predefined time period (*i.e.*, a "symbol period"). Second, "symbol" can refer to all of the information transmitted on all of the carriers in a symbol period. The individual carrier symbols are often referred to as "QAM symbols," where "QAM" (Quatrature Amplitude Modulation) is a commonly-used type of modulation used to modulate a carrier symbol onto a carrier. A multicarrier "symbol" (*i.e.*, the collection of multiple carrier symbols) is often referred to as a "DMT symbol," where "DMT" (Discrete Multitone) is a type of multicarrier technology. *See* Ex. 2003 at ¶ 33.

In order to keep things clear and to avoid apparent inconsistency/overlap with the term "symbol," this Patent Owner Response and accompanying declaration employ the terms "carrier" and "symbol" as follows:

- "carrier" means a carrier symbol (*e.g.*, a QAM symbol); and
- "symbol" means a collective multicarrier symbol in a single symbol period (*e.g.*, a DMT symbol).

See Ex. 2003 at ¶ 34. This Patent Owner Response and accompanying declaration also use appropriate editorializing to distinguish between a "carrier" and a "symbol" in the references of record, the Petition, and Petitioners' expert's declaration. *See id.* at ¶ 35.

Further adding to potential confusion is that the terms “carrier,” “subcarrier,” “band,” “sub-band,” “bin,” “channel,” and “tone” are often used interchangeably. Ex. 1011 at 1:42–43 (“sub-bands or frequency bins”); *id*. at 1:48 (“sub-band channels”); *id*. at 5:13–15 (“carrier”); *id*. at 10:40–41 (“subcarriers”); *id*. at 12:39 (“bin (channel)”); Ex. 1012 at 1:41 (“tones or bands”). For consistency, Patent Owner has used the term “carrier” as much as possible in this Patent Owner Response and accompanying declaration. *See* Ex. 2003 at ¶ 36.

III. CLAIM CONSTRUCTION

Petitioners proposed to construe two claim terms: “multicarrier” and “transceiver.” Patent Owner maintains that it is not necessary to construe either of these terms to resolve the issues at hand.

Additionally, Patent Owner proposes to construe “scramble…a plurality of carrier phases” to mean “scramble a plurality of carrier phases in a single multicarrier symbol.”

A. “Multicarrier”

With respect to “multicarrier,” the Board agreed with Patent Owner that there is no need to construe this term for the purposes of the institution decision.

B. “Transceiver”

While the Board opted to construe “transceiver,” Patent Owner maintains that a construction is not necessary to evaluate the grounds of unpatentability

presented by the Petitioners. The Board adopted Petitioners' proposal, namely that a "transceiver" is "a device, such as a modem, with a transmitter and a receiver." Institution Decision, Paper No. 7 at p. 7. In a corresponding district court matter, Patent Owner proposed to construe "transceiver" to mean "a communications device capable of transmitting and receiving data over the same physical medium wherein the transmitting and receiving functions are implemented using at least some common circuitry." Ex. 2007 at p. 8. The district court construed "transceiver" to mean "a communications device capable of transmitting and receiving data wherein the transmitter portion and receiver portion share at least some common circuitry." *See id.* at pp. 8–9. Petitioners' arguments fail irrespective of which of the foregoing constructions for "transceiver" is used.

C. "Scrambling The Phase Characteristics Of The Carrier Signals"

In the context of the '158 patent, "scrambling the phase characteristics of the carrier signals" (claim 1) should be construed to mean "adjusting the phases of a plurality of carriers in a single multicarrier symbol by pseudo-randomly varying amounts." This construction is fully supported by the specification of the '158 patent, and it clarifies that the claimed phase scrambling must be performed amongst the individual carrier phases in a single multicarrier symbol. In other words, the claimed phase scrambling is not met if the phase adjustment only occurs over time from one symbol to the next. *See* Ex. 2003 at ¶ 37.

The ’158 patent is directed exclusively to multicarrier modulation systems. *See* Ex. 1001 at 1:28–31 (“This invention relates to communications systems using multicarrier modulation. More particularly, the invention relates to multicarrier communications systems that lower the peak-to-average power ratio (PAR) of transmitted signals.”); 3:34–39 (“Although described with respect to discrete multitone modulation, the principles of the invention apply also to other types of multicarrier modulation, such as, but not limited to, orthogonally multiplexed quadrature amplitude modulation (OQAM), discrete wavelet multitone (DWMT) modulation, and orthogonal frequency division multiplexing (OFDM).”). Furthermore, every independent claim is directed to a “multicarrier modulation system” (claims 1 and 15). The ’158 patent discloses several multicarrier techniques and uses “discrete multitone modulation” (“DMT”) as an example. *Id.* at 3:34–39. *See* Ex. 2003 at ¶ 38.

As discussed above in § II.A, a multicarrier signal includes the combination of a plurality of carriers, where each carrier has a different frequency and its own phase. In the embodiment of the ’158 patent, each of the plurality of carriers corresponds to a different QAM symbol. *See, e.g.,* Ex. 1001 at 4:15–16 (“The modulator 46 modulates each carrier signal with a different QAM symbol 58.”).

Each carrier (or QAM symbol) has its own phase or phase characteristic.[3] *See*, *e.g.*, *id.* at 4:9–11 ("The QAM symbols 58 represent the amplitude and the phase characteristic of each carrier signal."). The combination of these carriers (or QAM symbols) is referred to as a DMT symbol (which is an exemplary type of multicarrier symbol). *See, e.g.*, *id.* at 9:8–9 ("…a set of QAM symbols 58 produces a DMT symbol 70…."). *See* Ex. 2003 at ¶ 39.

The '158 patent repeatedly discloses a "phase scrambler" that scrambles the phases or phase characteristics of carriers within a single DMT symbol. *See* Ex. 1001 at 6:53–8:13. As the '158 patent explains, PAR in the transmission signal is reduced by adjusting the carrier phases within a single DMT symbol. *See id.* at 6:32–53. If the carrier phases were only adjusted from one symbol to the next, PAR would not be reduced. *See* Ex. 2003 at ¶¶ 41–42.

In a corresponding district court matter, the court construed "scrambling the phase characteristics of the carrier signals" to mean "adjusting the phase characteristics of the carrier signals by pseudo-randomly varying amounts." Ex.

[3] The term "phase characteristic" in the '158 patent is interchangeable with "phase." *See* Ex. 1001 at 1:42–44 ("The DMT transmitter typically modulates the phase characteristic, or phase, and amplitude of the carrier signals…."). *See* Ex. 2003 at ¶ 40.

2007 at pp. 10–11. During prosecution of a child application to the ’158 patent (U.S. Pat. No. 9,014,243), the applicant explained that a “scrambler” operates “by pseudo-randomly selecting bits to invert.” Ex. 2008 at p. 18. There was no fundamental disagreement between parties that scrambling involves adjusting the phase characteristics of a carrier signal by pseudo-randomly varying amounts. Ex. 2007 at pp. 10–11.

Furthermore, when Petitioners’ expert was asked about his application of the claims to the asserted Stopler reference, he expressed his opinion that the claims require phase scrambling within a single multicarrier symbol. In his declaration, he contends that the claims are invalid over a combination of at least Shively and Stopler. Ex. 1009 at ¶¶ 54, 72, 85, 94, and 98. Pertinently, he alleges that Stopler discloses the claim recitation of “scrambling the phase characteristics of the carrier signals.” *Id.* at p. 41–45 (element “1.3”).

During cross-examination, Petitioners’ expert discussed his opinion that Stopler discloses scrambling within a single multicarrier symbol. Indeed, he specifically rejected that Stopler’s phase scrambling could be performed from one multicarrier symbol to the next. Note, in the transcript excerpt below, a “DMT symbol” refers to a single multicarrier symbol, while a “QAM symbol” refers to a single carrier in the DMT (or multicarrier) symbol.

> Q. But you didn't take into consideration when you interpreted that [section of Stopler], that it may be talking about randomizing

> overhead channels from [one] DMT symbol to the next, did you?
>
> A. The natural interpretation, since Stopler is teaching how to randomize plural overhead channel symbols [*i.e.*, "carriers"], the natural interpretation is that each symbol [*i.e.*, "carrier"] would have a different phase rotation.
>
> ***Q. So you're suggesting that each symbol from one symbol to the next would have a different phase rotation?***
>
> ***A. No. No. Individual QAM symbols [i.e., "carrier"] within the same modulation block [i.e., "symbol"].***
>
> Q. Where does it say that?
>
> A. If you read the paragraph, "The input to the QAM mapper 82"—we're on column 12, line 21. "The input to the QAM mapper 82 is data in the form of m-tuples which are to be mapped into QAM symbols"—basically getting m-tuples, mapping them to one QAM symbol—"for example, ranging from QPSK to 256-QAM tone by tone." So in the context of QAM mapper 82, which is in Figure 5, this block is processing at the QAM symbol by the QAM symbol, so each QAM symbol is processed individually. The constellation mapping may be the same as that used in ADSL. So again, it uses ADSL as an example. "In order to randomize the overhead channel symbols, a phase scrambling sequence is applied to the output symbols." It's in the context of QAM mapper 82 mapping m-tuples groups of bits into QAM symbols, one symbol at a time, tone by tone, inserting overhead channel symbols, which are plural, and phase scrambling is applied to these symbols. ***My interpretation has been applied on a QAM symbol by QAM symbol [i.e., "carrier by carrier"].***

Ex. 2002 at 107:7–108:18 (emphasis added). *See, more generally, id.* at 104:20–109:5.

Thus, Petitioners' expert has interpreted the claim term "scrambling the phase characteristics of the carrier signals" to require adjusting the phases of a plurality of carriers within a single multicarrier symbol. Consequently, the term

"scrambling the phase characteristics of the carrier signals" should be construed to mean "adjusting the phases of a plurality of carriers in a single multicarrier symbol by pseudo-randomly varying amounts." *See* Ex. 2003 at ¶ 37.

IV. OVERVIEW OF ASSERTED REFERENCES—SHIVELY AND STOPLER

In every instance, Petitioners allege that the challenged claims are unpatentable at least over Shively in view of Stopler.

A. Shively

Shively discloses a concept intended to increase the useable bandwidth in a multicarrier communications system. Ex. 1011 at 1:5–20. Shively teaches a theoretical way to transmit data over a transmission medium having high signal attenuation at frequencies corresponding to a significant number of carriers. *See* Ex. 2003 at ¶ 43.

To appreciate Shively's teachings, it necessary to understand such impaired transmission mediums. Shively specifically describes "long loop" systems, where the length of cable between transmitting and receiving DSL modems is ***at least*** 18,000 feet (about 3.4 miles):

> Referring to FIGS. 1 and 2, a transmitting modem 31 is connected to a receiving modem 32 by a cable 33 having four twisted pairs of conductors. In long loop systems where cable 3 is of length of the order ***18,000 feet or more***, high signal attenuation at higher frequencies (greater than 500 kHz) is usually observed. This characteristic of cable 33 is represented graphically by curve A in FIG. 1.

Ex. 1011 at 9:63–10:2 (emphasis added); *see also, id.*, at 11:11–12 ("Such noisy and/or highly attenuated sub-bands can occur for example in long-run twisted pair conductors."). *See* Ex. 2003 at ¶ 44.

FIG. 1 of Shively, which is annotated with color below, is illustrative:

FIG. 1

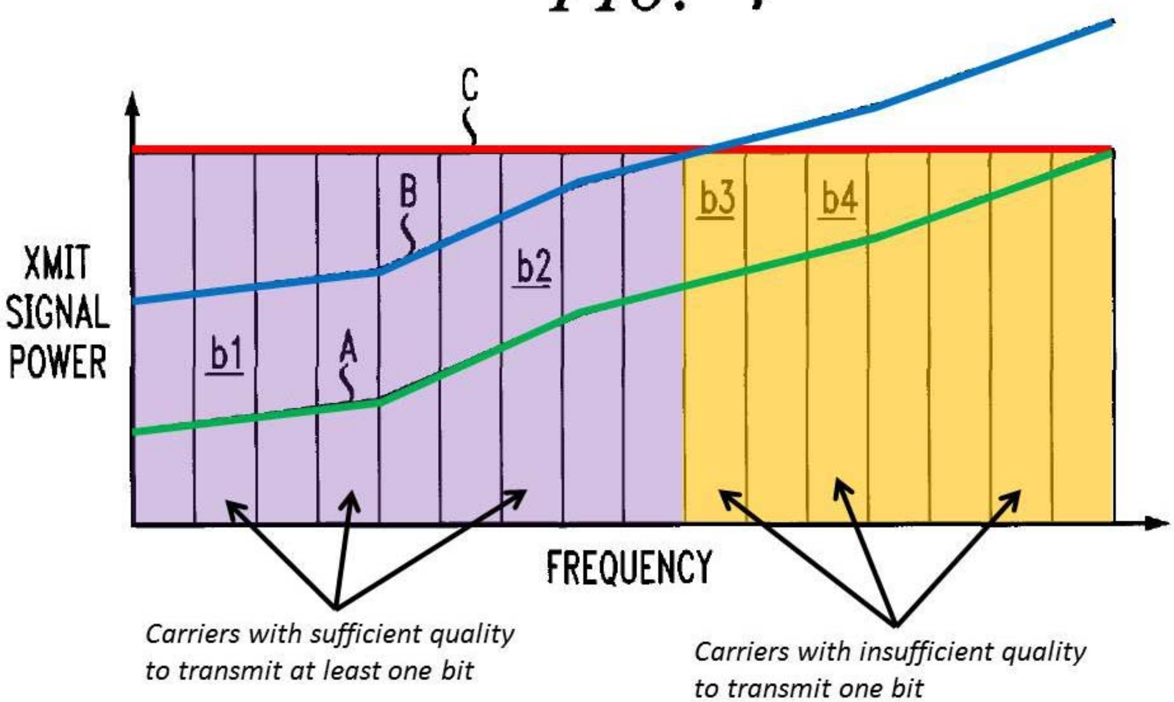


FIG. 1 of Shively shows carriers at increasing frequencies along the x-axis. Each carrier is delineated by vertical lines. Power level is indicated along the y-axis. Green line (A) represents an attenuation/noise floor, which increases as a function of frequency. Ex. 1011 at 2:1–12. Shively explains that attenuation at higher frequencies is a problem across long cables. *Id.* at 9:65–10:2 ("In long loop systems where cable 3 is of length of the order 18,000 feet or more, high signal

attenuation at higher frequencies (greater than 500 kHz) is usually observed."). Green line (A) is a characteristic of a communications channel, and it does not illustrate a transmitted signal. *Id.* at 10:61–11:12. *See* Ex. 2003 at ¶ 45–46.

Blue line (B) is the minimum power margin above the attenuation/noise floor (green line (A)) that is required to transmit a single bit on a given carrier. Ex. 1011 at 2:8–10. Red line (C) illustrates a "spectral density mask," which is a type of power limit imposed by system design. *Id.* at 2:10–12 ("Curve C represents the limits imposed by a power spectral density mask imposed by an external communications standard."). Power transmitted on a given individual carrier cannot exceed red line (C). *See* Ex. 2003 at ¶ 47.

As FIG. 1 illustrates, blue line (B) is below red line (C) for the carriers shaded in purple. In these purple-shaded carriers, there is sufficient headroom to transmit a signal representing at least one bit without exceeding the power limit imposed by the spectral density mask (red line (C)). For the carriers shaded in orange, however, blue line (B) exceeds red line (C). Because the attenuation/noise (green line (A)) for these orange-shaded carriers is too high, a bit cannot be reliably transmitted without exceeding the imposed spectral density mask (red line (C)). In other words, the minimum required power margin (blue line (B)) is greater than the spectral density mask (red line (C)). Ex. 1011 at 10:65–11:3. *See* Ex. 2003 at ¶ 48.

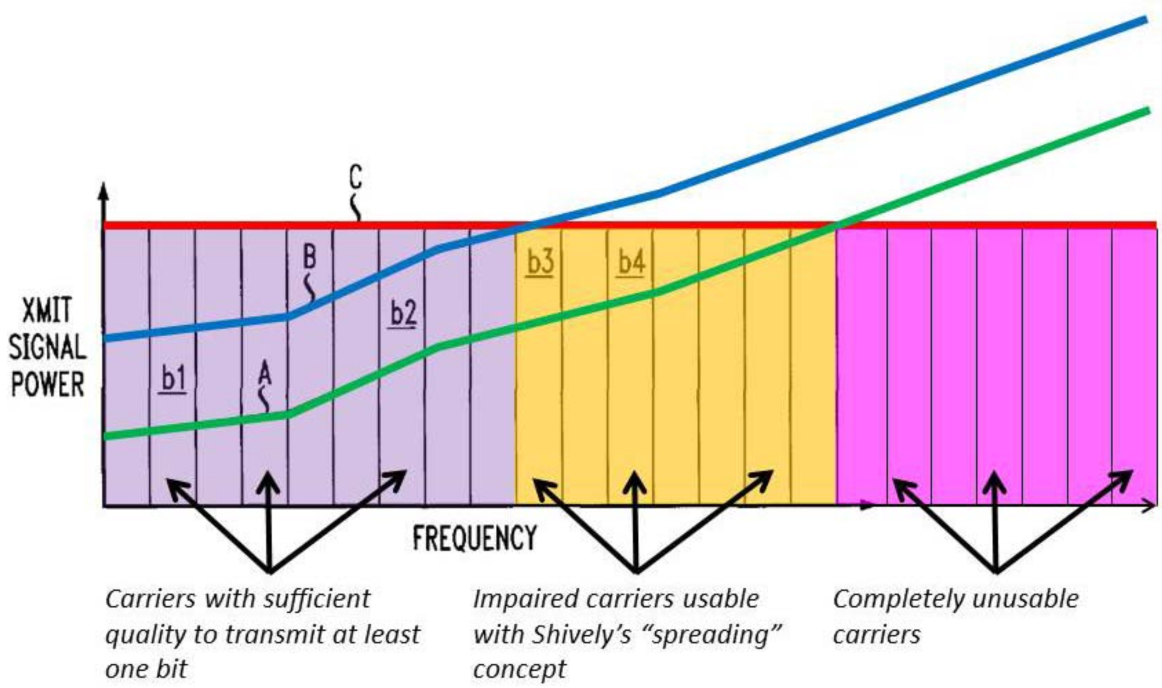
Shively proposes a way to transmit data using some of the impaired (orange-shaded) carriers. Specifically, some of the impaired carriers, although having insufficient channel quality to transmit a single bit, have some limited power available between the attenuation/noise floor (green line (A)) and the spectral density mask (red line (C)). Shively makes use of this available power by "spreading" a single bit of data across multiple impaired carriers. *See* Ex. 2003 at ¶ 49.

Shively's receiver combines (adds) the signals that were sent on the impaired carriers to recover the information:

> According to the invention, digital modulator 14 replicates ("spreads") a k-bit symbol over multiple adjacent bands with correspondingly less energy in each band. At the receiving end, detector 49 coherently recombines ("despreads") the redundant symbols in the noisy/attenuated sub-bands. In recombining the symbols, the symbols are simply arithmetically added. Because the noise is incoherent while the signal is coherent, the noise tends to be averaged out while the signal is reinforced by the addition process.

Id. at 11:16–24. *See* Ex. 2003 at ¶ 50.

Although not explicitly depicted in FIG. 1, one having ordinary skill in the art understood that there are carriers in addition to those shaded in purple and orange that are completely unusable under any circumstance—even with Shively's spreading concept. According to this reality, FIG. 1 can be expanded to look like this:



Ex. 2003 at ¶ 51.

The pink-shaded carriers are at frequencies higher than the orange-shaded carriers. The pink-shaded carriers are completely unusable because the attenuation/noise floor (green line (A)) is greater than the imposed spectral density mask power limit (red line (C)). *See* Ex. 2003 at ¶ 52.

Shively discloses two different modes of operation for ADSL-1995: (1) a normal mode; and (2) a "power-boost" mode. The normal mode is referenced by Shively's statement that: "The other limit is on the aggregate power, also defined by an external communication standard, e.g., ANSI Standard T1.413-1995 [(ADSL-1995)] limits the total power for all sub-bands to 100 mWatts." Ex. 1011 at 2:12–15. When referring to the cited ADSL-1995 standard, one having ordinary

skill in the art would have understood that this aggregate power limit corresponds to the normal mode. The standard confirms that the normal mode has an aggregate power limit of 20.4 dBm, which is about 109.6 mW (or approximately 100 mW). Ex. 1018 at p. 65. § 6.13.3 ("The normal aggregate power level shall not exceed…20.4 dBm if all sub-carriers are used[]."). *See* Ex. 2003 at ¶ 53.

The power-boost mode of ADSL-1995 is also described by Shively:

> The power spectral density mask may be dictated by the standard used in a particular country implementing the standard (such as A.N.S.I. standard T1.413-1995 [(ADSL-1995)])…For example, the power limit for frequencies or tones between 0 and 200 kilohertz must be less than -40 dBm/Hz (a power level referenced to one milliwatt over 1 Hz bandwidth). Above 200 kHz (to frequencies in the megahertz of spectrum), the constraint may be -34 dBm/Hz.

Ex. 1011 at 1:51–65. When referring to ADSL-1995, one having ordinary skill in the art would have understood that this spectral density mask scheme—lower power (-40 dBm/Hz) on carriers at frequencies up to 200 kHz and higher power (-34 dBm/Hz) on carriers at frequencies above 200 kHz—describes the ADSL-1995 power-boost mode. *See* Ex. 2003 at ¶ 54.

The power-boost mode is illustrated below in a figure excerpted from the ADSL-1995 standard, Ex. 1018 at p. 66:

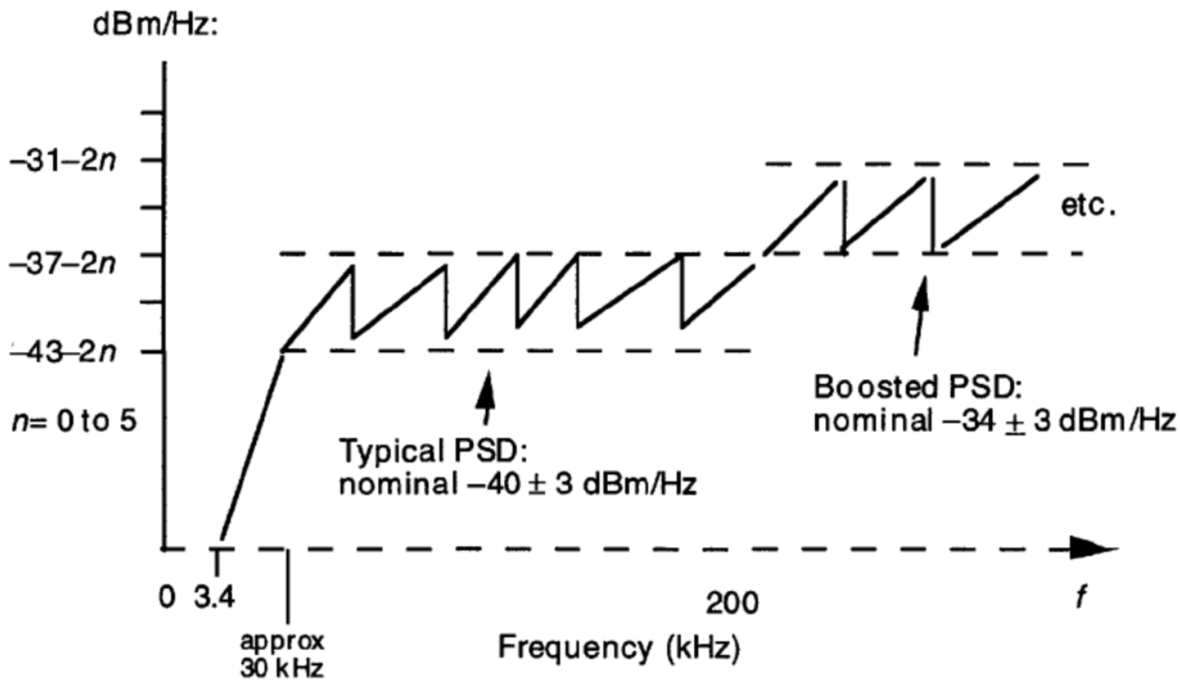


Figure 18 – ATU-C transmitter PSD mask: pass-band detail

Note, in the figure above, "PSD" stands for power spectral density, which corresponds to the spectral density mask power limit. *See id.* at p. 61, § 6.8. *See* Ex. 2003 at ¶ 55.

While the normal mode has an aggregate power limit of approximately 100 mW, the aggregate limit of the power-boost mode is approximately 344 mW. *See* Ex. 1018 at p. 66 ("a power boost…total power = the sum of the powers (-4 + 10log(*ncdown1*)) and (2 + 10log(*ncdown2*)), where *ncdown1* and *ncdown2* are the number of subcarriers used in the sub-bands *i* = 0 to 50, and *i* = 51 to 255, respectively."). Petitioners' expert, however, misunderstood Shively by imagining that a 100 mW aggregate power limit would be used in the power-boost mode. In

particular, during cross-examination regarding the bases for his opinions regarding Shively, he testified that he interpreted Shively as disclosing a single mode in which the spectral density mask is -40 dBm/Hz for carriers in the frequency band up to 200 kHz and -34 dBm/Hz for carriers in the frequency band above 200 kHz and an aggregate power limit of approximately 100 mW. Ex 2002 at 43:7–25; *see, more generally, id*. at 42:10–46:12. But this is clearly wrong because it is wholly inconsistent with the ADSL-1995 standard to which Shively's disclosure is directed. *See* Ex. 2003 at ¶ 56.

Indeed, having such a low aggregate power limit (100 mW, which is less than 1/3 of the actual 344 mW aggregate power limit of power-boost mode in ADSL-1995) would defeat the purpose of having a power-***boost*** mode. Notwithstanding Petitioners' expert's mistaken understanding of Shively—which mixed the aggregate power limit of normal mode with the spectral density mask of power-boost modes—one having ordinary skill in the art would have readily paired the correct aggregate power limit and spectral density mask for a particular mode when consulting the ADSL-1995 standard to which Shively's disclosure is directed.[4] *See* Ex. 2003 at ¶ 57.

[4] To the extent Shively is incorrectly interpreted as disclosing a single mode in which the spectral density mask is -40 dBm/Hz for carriers having frequencies up

In Shively's proposed system using normal mode for ADSL-1995 across 18,000 foot wires, and given the average attenuation/noise characteristics of such a long-loop, about 34% of the carriers would be unimpaired (*i.e.*, would fall into the purple-shaded region of the figure on page 23 *supra*), about 6% of the carriers would be impaired (*i.e.*, would fall into the orange-shaded region of the figure on page 23 *supra*), and about 60% of the carriers would be unusable (*i.e.*, would fall into the pink-shaded region of the figure on page 23 *supra*). Thus, ***more than half of the carriers cannot be used at all***. Consequently, the power of a transmitted signal will be reduced by 60%, thereby resulting in power levels only 40% of maximum. *See* Ex. 2003 at ¶¶ 58–59.

In Shively's proposed system using power-boost mode for ADSL-1995

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to 200 kHz and -34 dBm/Hz for frequencies above 200 kHz (as is the case for boosted mode of ADSL-1995) and a total power limit of approximately 100 mW (as is the case for the normal mode of ADSL-1995), one of skill in the art would recognize this as an obvious error (Ex. 2003 at ¶ 57). *See In re Yale*, 434 F.2d 666, 668–69 (C.C.P.A. 1970) ("Since it is an obvious error, it cannot be said that one of ordinary skill in the art would do anything more than mentally disregard [the incorrect chemical] as a misprint or mentally substitute [the correct chemical] in its place.").

across 18,000 foot wires, and given the average attenuation/noise characteristics of such a long-loop, about 43% of the carriers would be unimpaired (purple-shaded), about 6% of the carriers would be impaired (orange-shaded), and about 51% of the carriers would be unusable (pink-shaded). Again, more than half of the carriers cannot be used at all. Consequently, the power of a transmitted signal will be reduced by 51%, thereby resulting in power levels only 49% of maximum. *See* Ex. 2003 at ¶ 60–61.

While Shively's "spreading" technique will contribute a small uptick in clipping probability, any increase would be negated by the enormous reduction in clipping probability achieved by reducing signal power by more than half. Based on worst-case assumptions regarding Shively's spreading technique, the clipping probability for both normal and power-boost modes is virtually zero.[5] *See* Ex. 2003

[5] For the normal mode, the clipping probability is $8.3*10^{-17}$. *See* Ex. 2003 at ¶ 63–67. Assuming a sampling rate of 2.2 MHz for ADSL-1995, this would result in a clipping error ***once every 173.7 years***, on average. *Id.* For the power-boost mode, the clipping probability is $1.4*10^{-15}$. *Id.* Using the same assumption for sampling rate, this would result in a clipping error ***once every 10.3 years***, on average. *Id.* These numbers are many orders of magnitude larger than the error rate of 4.55 seconds discussed above.

at ¶ 63–67.

For cable lengths longer than 18,000 feet, an increasing number of carriers becomes unusable (pink-shaded), resulting in even greater reductions in clipping probabilities. *See* Ex. 2003 at ¶ 68.

Not surprisingly, Shively does not mention anything about clipping or PAR. Petitioners' expert agreed:

> Q. Okay. Can you tell me, does the Shively reference include any discussion of PAR?
>
> A. I don't remember seeing it.
>
> Q. Okay. Does Shively include any explanation it's spreading invention causes an increase in PAR?
>
> A. I don't remember seeing that.
>
> Q. Does Shively explain anywhere that its spreading invention would cause a PAR problem?
>
> A. I don't remember seeing that.
>
> Q. Okay. So the Shively reference itself does not indicate that its invention creates any issue with PAR; right?
>
> A. I didn't see it.

Ex. 2002 at 14:2–15.

B. Stopler

Unlike Shively, Stopler proposes an idea for use with ***both*** multicarrier systems ***and*** "single-carrier" systems. While multicarrier systems transmit a transmission signal that combines multiple carriers each having a phase, a single-

carrier system transmits a signal using only one carrier, which has ***only one phase***. *See* Ex. 2003 at ¶ 69.

Stopler specifically teaches that his concept can be used with single-carrier code-division multiple access ("CDMA") systems. *See, e.g.,* Ex. 1012 at 12:58–63 ("The framing scheme according to the present invention may also be performed in a CDMA system, in which case the modulator (not shown) may, for example, be a CDMA-type modulator in accordance with the TIA/EIA/IS-95 'Mobile Station Compatibility Standard for Dual Mode Wideband Spread Spectrum Cellular System.'").[6] *See* Ex. 2003 at ¶ 70.

FIG. 5, which shows Stopler's "framing scheme" (Ex. 1012 at 8:54–55), is illustrative:

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[6] As Petitioners' expert explained during cross-examination, some CDMA techniques can be used in a multicarrier system. Ex. 2002 at 110:20–25. However, Stopler only refers to CDMA techniques that are disclosed in two references: (1) TIA/EIA/IS-95; and (2) "Proakis, 'Digital Communications,' Chapter 15." Ex. 1012 at 3:37–47 and 12:58–63. Both TIA/EIA/IS-95 and Proakis are incorporated by reference into Stopler. *Id.* at 3:37–47. Both describe single-carrier CDMA techniques, exclusively. *See* Ex. 2005; Ex. 2006; Ex. 2003 at ¶ 71.

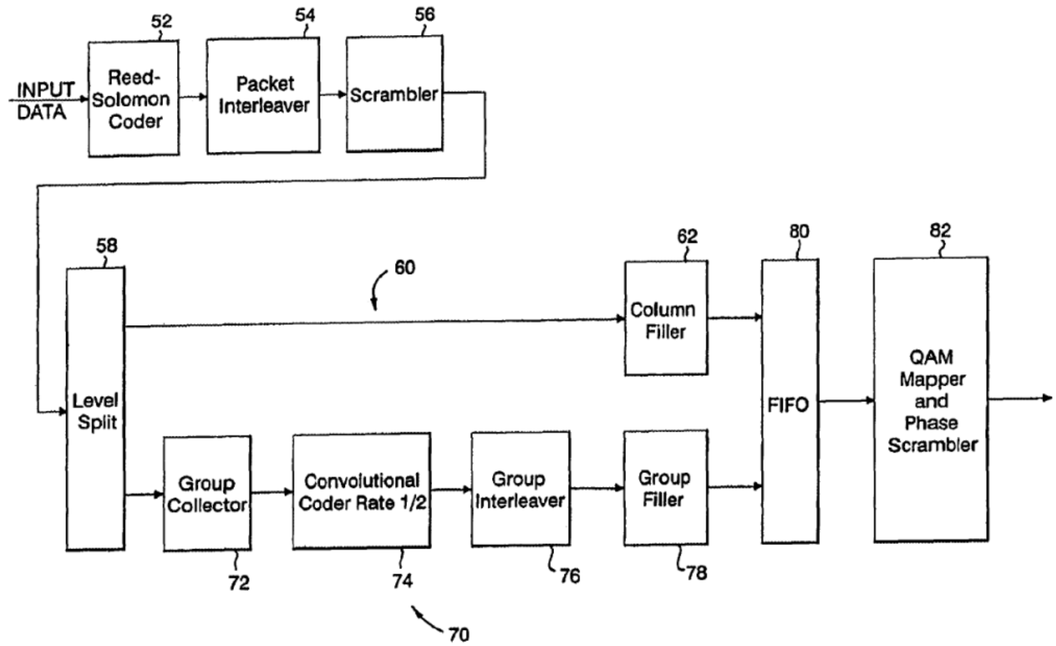


FIG. 5

See Ex. 2003 at ¶ 72.

Significantly, there is a block missing from FIG. 5—namely, a block downstream from the QAM Mapper/Phase Scrambler 82:

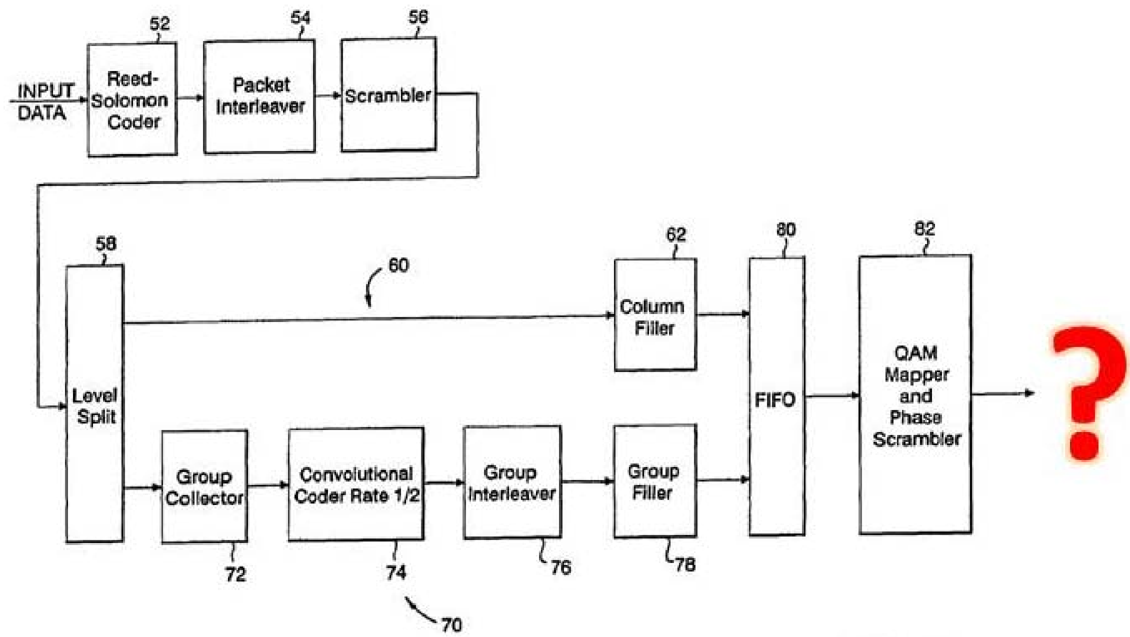
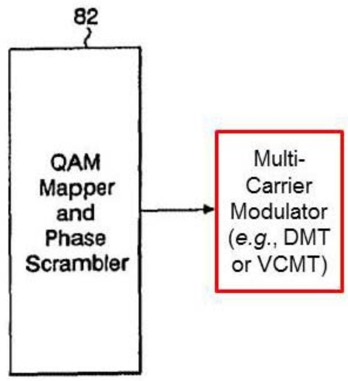


FIG. 5

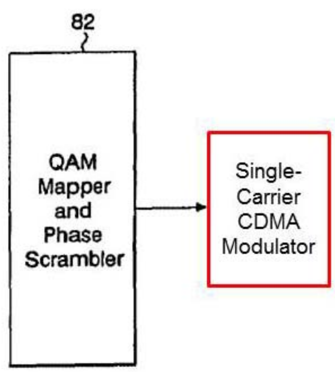
See Ex. 2003 at ¶ 73.

The missing block would specify the type of "modulation" to be used, whether the modulation be single-carrier or multicarrier. *See* Ex. 1012 at 12:55–57 ("The output from the QAM mapper 82 is provided to ***a modulator (not shown)*** which implements the particular signal modulation desired, e.g., VCMT, CDMA, etc.") (emphasis added).[7] *See* Ex. 2003 at ¶ 74. So the missing block downstream from the QAM Mapper/Phase Scrambler 82 could be a multicarrier modulator:

[7] Note, VCMT stands for "variable constellation multitone." *See id.* at 2:9. This is a type of multicarrier technique. Ex. 2003 at ¶ 74.



Or the missing block could be a single-carrier modulator:



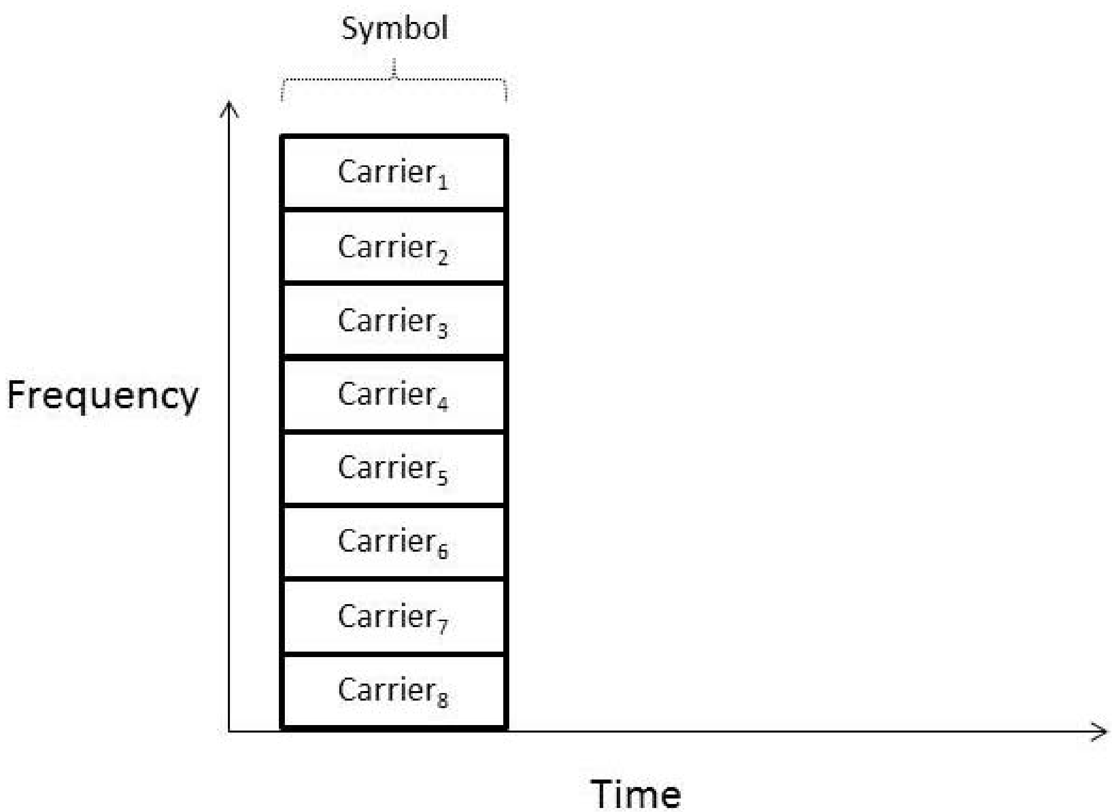
See Ex. 2003 at ¶ 76.

In either case, Stopler's phase scrambling scheme must at least be compatible with single-carrier CDMA. This fact is reflected in Stopler's claims. For example, claim 25 of Stopler recites a "method of arranging and transmitting data in a ***CDMA system***." Ex. 1012 at 16:4–5 (emphasis added). And claim 31, which depends from claim 25, recites "phase scrambling": "31. The method of claim 25, wherein prior to said utilizing step, said method includes the step of ***phase scrambling*** said upper level data and said second encoded data in

accordance with said second encoded data." *Id*. at 16:45–48 (emphasis added). So, plainly, Stopler's phase scrambling idea must be compatible with single-carrier CDMA. *See* Ex. 2003 at ¶ 76.

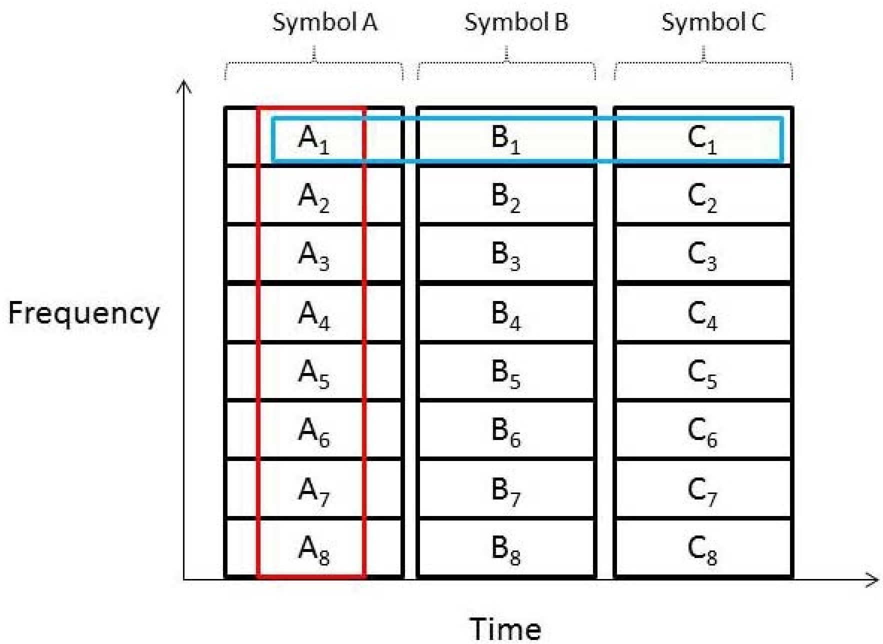
At issue in this IPR is whether Stopler's phase scrambling is performed within a single multicarrier symbol, or whether phase scrambling is performed amongst a plurality of symbols (be they multicarrier or single-carrier), each transmitted at a different time. Because Stopler discloses and claims phase scrambling with a single-carrier CDMA system, one of skill in the art would understand Stopler to disclose the latter—phase scrambling is performed across different symbols in time. Phase scrambling is not performed within a single multicarrier symbol.

Consider the following illustration of a multicarrier symbol:



The symbol includes eight carriers—Carrier$_1$ to Carrier$_8$. Each carrier has an associated phase. According to Petitioners' incorrect argument, Stopler discloses scrambling the phases of Carrier$_1$–Carrier$_8$. Petition at p. 15 ("Stopler teaches that a phase scrambler can be employed to randomize the phase of the individual [carriers].").

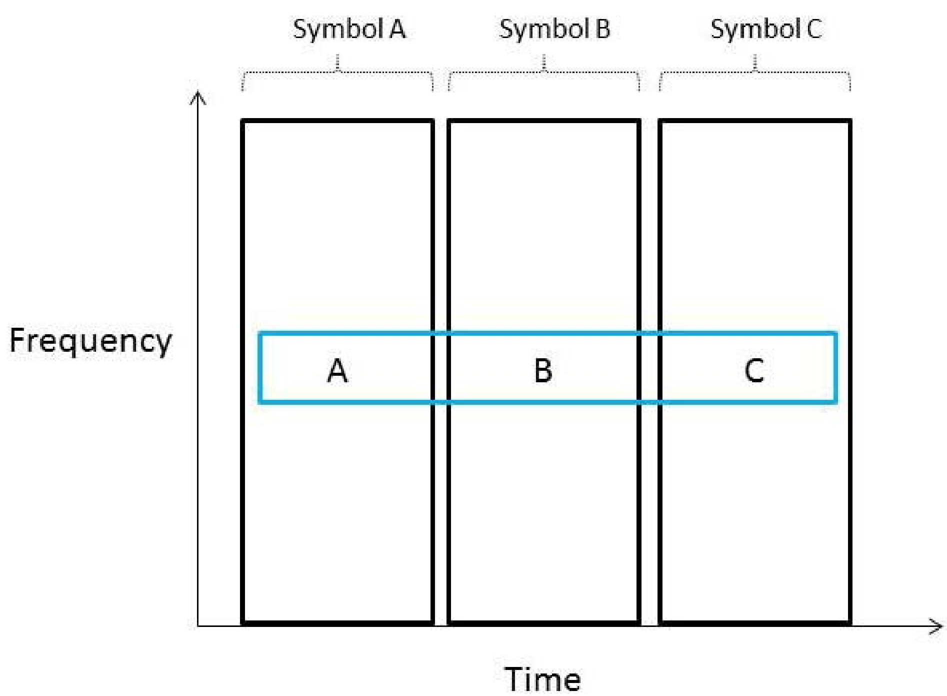
Consider now that three multicarrier symbols are transmitted at different times:



Petitioners argue that Stopler's phase scrambling is performed vertically, within the red box—*i.e.*, within one symbol. Petitioners' expert further asserted (during cross-examination) that Stopler's phase scrambling is not performed horizontally from symbol-to-symbol—*e.g.*, within the blue box. Ex. 2002 at 107:15–18 ("Q. So you're suggesting that each symbol from one symbol to the next would have a different phase rotation? A. No. No. Individual QAM symbols within the same modulation block."); *see, more generally, id.* at 104:20–109:5. This is wrong. *See* Ex. 2003 at ¶ 77.

Petitioners' flawed reasoning is easy to demonstrate, given that single-carrier CDMA must be operable with Stopler's phase scrambling. Single-carrier systems have only one carrier with only one phase. Consider three single-carrier

symbols sent at different times:



It is nonsensical to scramble phases within a symbol because there is only one phase in each symbol. Phase scrambling in a single-carrier system only makes sense when it is performed over time from symbol-to-symbol, as illustrated by the blue box. *See* Ex. 2003 at ¶ 78.

There are various reasons that would have been recognizable to one having ordinary skill in the art for performing phase scrambling from symbol-to-symbol. For example, Petitioners' expert suggested that pilot tones could be scrambled over time "not to create a DC bias." Ex. 2002 at 95:7–9; *see, more generally, id.* at 95:3–17. *See* Ex. 2003 at ¶ 79.

Another example for phase scrambling from symbol-to-symbol is detailed in U.S. Pat. No. 6,370,156 ("the '156 patent"), which has a priority date of January 31, 1997 (which is before the November 9, 1999 priority date of the '158 patent). The '156 patent identifies a problem of "narrowbanded" interference in ADSL-1995. Ex. 2004 at 1:55–2:16. This identical problem is also discussed in Stopler, as depicted in FIG. 4:

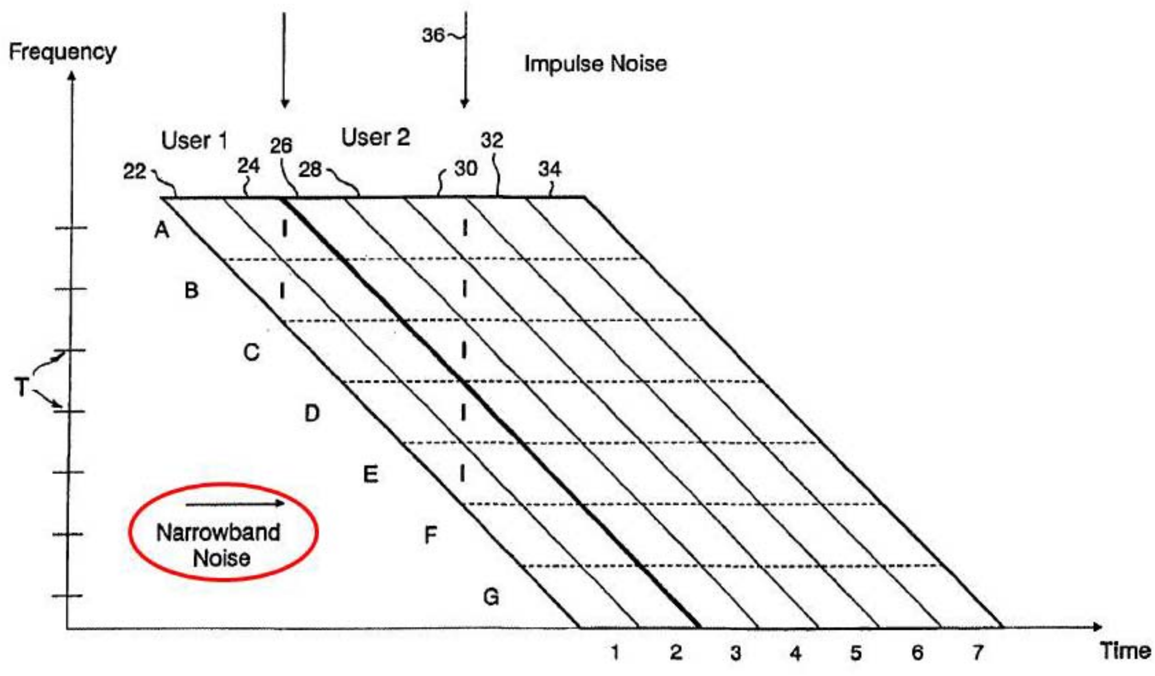


FIG. 4

See Ex. 2003 at ¶ 80.

Stopler further explains: "One type of noise is ingress or narrowband interference which typically occurs at a fixed frequency and lasts for a long time." Ex. 1012 at 1:36–38. Stopler claims that his "invention" "allows efficient

operation in multipoint to point channels which are affected by ingress (narrowband noise) and impulsive (burst) interference." *Id.* at 5:10–14. *See* Ex. 2003 at ¶ 81.

Stopler addresses narrowband noise in two ways. First, as shown in Figure 4 reproduced above, a given carrier (*e.g.*, carrier E) is assigned to a first user (*e.g.*, User 1) at some times and to a different user (*e.g.*, User 2) at other times. If narrowband noise corrupts carrier E, the resulting bit errors have reduced impact on each user compared to a system in which a given carrier is always assigned to a single user. *See* Ex. 2003 at ¶ 82.

This solution works for data, but it will not work for an overhead pilot carrier because such a pilot must be received by all users at all times to allow the receiver of each user to remain synchronized with the transmitter. Thus, narrowband noise at the frequency of pilot tones must be addressed differently. *See* Ex. 2003 at ¶ 82.

According to a second narrowband-noise-reducing technique, Stopler addresses narrowband noise at the frequency of an overhead pilot carrier by scrambling the phase of the pilot carrier over time from one DMT symbol to the next, *i.e.*, by ***inter***-symbol phase scrambling. *See* Ex. 2003 at ¶ 82.

The teachings of the '156 patent reveal how Stopler's inter-symbol phase scrambling concept reduces the problem of narrowband noise that interferes with a

pilot carrier. The '156 patent explains that ADSL-1995 has ***one*** carrier that is assigned to be a pilot. Ex. 2004 at 1:61–63 ("As is indicated in [the ADSL-1995 standard], one of the carriers is reserved as a pilot carrier."). Then, the technique of phase scrambling the pilot carrier from symbol-to-symbol is explained:

> In a particular implementation of the present invention, the pilot carrier is modulated as a random or pseudo-random signal. In this way, by modulating a randomised signal on the pilot carrier, the state of the pilot carrier in the constellation scheme ***will change randomly*** so that the demodulation will have a good averaging effect resulting in an ***increase of the interference immunity***.

Id. at 4:39–47 (emphasis added).

> It is to be remarked that, to have significant immunity against interferers, the data elements which are modulated on the pilot carrier, [have] to be sufficiently ***random*** so that the pilot carrier reaches all states in the constellation scheme and a good averaging of the interference is obtained by demodulation. This can be obtained by ***scrambling***.

Id. at 5:11–17 (emphasis added). *See* Ex. 2003 at ¶ 83.

Petitioners' argument that Stopler discloses phase scrambling within one symbol is based on the premise that the symbol can have multiple pilot tones. Yet the Petition and accompanying declaration do not discuss or allude to even one system or standard that uses multiple pilot tones in a single symbol. Instead, Petitioners and their expert identify only ADSL (Petition at p. 13; Ex. 1009 at ¶ 58). But, as explained in Petitioners' own exhibit (Ex. 1018), ADSL has exactly ***one*** pilot tone in a symbol, not multiple pilot tones. Ex. 1017 at p. 62, § 6.9.1.2. *See* Ex. 2003 at ¶ 84.

Petitioners and their expert highlight the ADSL standard and admit that it is implemented in Stopler. Petition at p. 13 ("Stopler also explains that its signal transmission scheme may implement techniques of DSL standards such as 'ADSL (Asymmetric Digital Subscriber Line).'"); Ex. 1009 at ¶ 58. Starting with the next sentence, Petitioners and their expert state:

> Stopler also explains that some of the available carriers may be reserved for the transmission of overhead signals, such as pilot tones. Ex. 1012, 10:60–62 & 12:51–54. To randomize these overhead channels, Stopler employs a phase scrambler. Ex. 1012, 12:24–26. A POSITA would have understood that the values transmitted in an overhead channel may not be random, and in fact, ***may be highly structured***. Ex. 1009, p. 26. Without the phase scrambler, the ***structured*** nature of the overhead channel could contribute to an increase in the peak-to-average power ratio of the transmitter. *Id.*

Petition at pp. 13–14 (emphasis added); *see also* Ex. 1009 at ¶ 59. *See* Ex. 2003 at ¶ 85.

Petitioners' expert, upon cross-examination, clarified that what he meant by "highly structured" is that multiple pilot tones are present in a single symbol. Ex. 2002 at 105:11–20 ("Q. …What do you mean by 'highly structured'? A. For example, if the pilot tone is the same value in all overhead channels, that's an example of structured; repeating the same value multiple times."); and 109:1–5 ("A.…[Stopler] specifically says 'overhead symbols,' which could be interpreted to having two or more overhead symbols in one block. And that was my interpretation. It still is my interpretation."); *see, more generally, id.* at 104:20–

109:5. *See* Ex. 2003 at ¶ 85

But Petitioners' expert ***did not even realize that ADSL has only <u>one</u> pilot tone***. Ex. 2002 at 90:11–14 ("Q. Okay. So in an ADSL system, according to the T1.413 standard, for example, there's a single pilot tone; correct? A. I don't know that."); *see, more generally, id.* at 90:4–91:16. At best, Petitioners' expert's declaration is based on incomplete information about ADSL. *See* Ex. 2003 at ¶ 85.

Instead of understanding that ADSL has only one pilot tone, Petitioners' expert based his opinion on the fact that Stopler refers to "overhead carriers" and that these multiple symbols must be in one symbol. Ex. 2002 at 109:1–5.[8] But the correct interpretation of Stopler's reference to plural "overhead carriers" is that (a) there is one overhead pilot carrier per symbol and (b) there are multiple symbols. *Ergo*, Stopler refers to multiple overhead carriers. *See* Ex. 2003 at ¶ 86.

As demonstrated by the '156 patent, it was known by those with skill in the

---

[8] Petitioners' expert specifically testified: "[Stopler] specifically says 'overhead symbols,' which could be interpreted to having two or more overhead symbols in one block. And that was my interpretation. It still is my interpretation." Ex. 2002 at 109:1–5. To clarify a matter of terminology, (1) "overhead symbols" correspond to "carriers," and (2) "block" corresponds to "symbol" as used in this Patent Owner Response. *See* Ex. 2003 at ¶ 86.

art to scramble the phases on a pilot carrier from one single-carrier symbol to the next in order to reduce the problem of narrowband noise, a problem recognized by Stopler. Petitioners' expert's uninformed view, by contrast, is that Stopler's phase scrambling would be performed within one multicarrier symbol to reduce PAR. Ex. 1009 at ¶ 60. Stopler, however, is silent on issues related to PAR, and, in fact, does not mention the word "power" or PAR, or teach that its disclosure could be used to resolve PAR problems, as confirmed by Petitioners' expert:

> Q. Okay. And Stopler does not mention peak-to-average power ratio, does it?
>
> A. I did not see it.
>
> Q. Okay. And it doesn't state anywhere that it's addressing a PAR issue; correct?
>
> A. I didn't see that.
>
> Q. And it doesn't say anywhere that its teachings could potentially reduce PAR; correct?
>
> A. I didn't see it.
>
> Q. Okay. Would you be surprised if I told you that the Stopler reference doesn't even mention the word "power"?
>
> A. I didn't see it. I'm not surprised.

Ex. 2002 at 97:6–18. *See* Ex. 2003 at ¶ 87.

Indeed, there is no reason that Stopler would discuss PAR because there is no basis for concluding that Stopler has a PAR problem, and Stopler's technique of scrambling phases from one symbol to the next does not reduce PAR. *See* Ex. 2003 at ¶ 88.

Instead of Petitioners' theory about reducing PAR, Stopler sheds some light as to why he suggests performing "phase scrambling." Stopler's only stated reason for scrambling phases is "to randomize the overhead channel symbols" plural. Ex. 1012 at 12:24–26. Because Stopler must be compatible with single-carrier CDMA as discussed above, the only reasonable conclusion is that Stopler's reference to "overhead channel symbols" plural refers to scrambling phases from symbol-to-symbol. *See* Ex. 2003 at ¶ 89.

Furthermore, Stopler states that the phase scrambler is "applied to all symbols, not just the overhead symbols" in order "to simplify implementation." But performing phase scrambling according to Petitioners' interpretation—*i.e.*, every carrier is scrambled within a symbol such that the signals on each of the carriers within a symbol have a random distribution of phase adjustments—would ***add complexity*** to Stopler's system. Instead, the only simplifying way to execute Stopler's directive is to adjust the phases of all carriers within a single symbol by the same amount. *See* Ex. 2003 at ¶ 90.

V. PETITIONERS HAVE NOT PROVEN UNPATENTABILITY FOR THE CLAIMS OF THE '158 PATENT

The Petition fails to prove, by a preponderance of the evidence, that any claim of the '158 patent is unpatentable because there is no credible or accurate evidence demonstrating why one having ordinary skill in the art would have combined Shively and Stopler. Additionally, with respect to claims 1–15, Stopler

does not disclose phase scrambling as recited. Furthermore, for claims 6–13, 20–28, and 30, Petitioners have not asserted a legally recognizable reason for combining Bremer with Stopler or Shively. Instead, Petitioners misunderstand the teachings of these references, make unsupported assumptions having no basis in fact, and, ultimately rely on only hindsight bias to cobble together the references.

A. Petitioners' Argued Reasons To Combine Shively And Stopler Are Without A Rational Basis, Based On Factual Errors, And Suffer From Hindsight Bias

Every assertion of invalidity (claims 1–30) is based on a combination of Shively and Stopler. But virtually all of Petitioners' (and Petitioners' expert's) assumptions regarding reasons to combine Shively and Stopler are without a rational basis, factually wrong, and suffer from hindsight bias.

1. Petitioners Provide No Explanation For The "Use Of A Known Technique To Improve A Similar Device" Rationale To Combine Shively And Stopler

Petitioners argue that the combination of Shively and Stopler "is merely a use of a known technique to improve a similar device, method, or product in the same way." Petition at p. 14. Petitioners, however, fail to apply this boilerplate rationale to Shively and Stopler, leaving the following questions unanswered. What is the "known technique"? What device/method/product is "similar"? How is the alleged "known technique" used for improvement in the "same way"?

When relying on this rationale, the USPTO requires much more in the way

of explanation:

> C. Use of Known Technique To Improve Similar Devices (Methods, or Products) in the Same Way
>
> To reject a claim based on this rationale, Office personnel must resolve the Graham factual inquiries. Office personnel must then articulate the following:
>
> (1) a finding that the prior art contained a "base" device (method, or product) upon which the claimed invention can be seen as an "improvement;"
>
> (2) a finding that the prior art contained a "comparable" device (method, or product that is not the same as the base device) that was improved in the same way as the claimed invention;
>
> (3) a finding that one of ordinary skill in the art could have applied the known "improvement" technique in the same way to the "base" device (method, or product) and the results would have been predictable to one of ordinary skill in the art; and
>
> (4) whatever additional findings based on the Graham factual inquiries may be necessary, in view of the facts of the case under consideration, to explain a conclusion of obviousness.

Examination Guidelines for Determining Obviousness Under 35 U.S.C. 103 in View of the Supreme Court Decision in *KSR International Co. v. Teleflex Inc*., 72 Fed. Reg. 57,530 (October 10, 2007). As the Board explained:

> Patent Owner argues that "(1) Petitioner NEVER explains what is allegedly lacking in the base reference, (2) Petitioner NEVER points out the differences between the claimed invention and the base reference or cited art, (3) Petitioner NEVER explains how the base reference should be allegedly modified, (4) Petitioner NEVER explains what modification would have been obvious, and (5) Petitioner NEVER explains what modifications to each base reference would have allegedly been made." Prelim. Resp. 47-48.
>
> We agree.

Naughty Dog, Inc. v. McRo, Inc., IPR2014-00198, Paper no. 9 at p. 21 (P.T.A.B. May 18, 2014).

In the present case, Petitioners' alleged reason to combine Shively and Stopler does not provide even basic answers to these questions.

2. Petitioners Wrongly Claim That Shively's Transmitter Suffers From An Increased PAR

Petitioners contend: "A POSITA would have recognized that by transmitting redundant data on multiple carriers, Shively's transmitter would suffer from an increased peak-to-average power ratio [(PAR)]." Petition at p. 14. As discussed above in § IV.A, however, this assertion is wrong. Shively does not suffer from an increased PAR, much less one that would be recognized as a problem. Rather, Shively's disclosed embodiment results in a substantially reduced PAR (and one that is very far below a level that is problematic).

Petitioners have it backwards. To the extent one having skill in the art would have even considered the issue of PAR in view of Shively's disclosure (which does not itself discuss PAR), they would have concluded that Shively's transmitter, in fact, does ***not*** suffer from increased PAR. Instead, there would have been recognition that the transmission signal strength is low due to unusable carriers, and therefore the clipping probability would be virtually zero. *See* § IV.A above.

Furthermore, Petitioners' expert's declaration states only in relative terms

that there is an "increase" in PAR. An "increase" of how much? An increase with respect to what? Petitioners' expert's declaration lacks any factual basis for the claim of "increased" PAR. Petitioners' expert provides no calculations or data that illustrate to what degree there is an "increase" in PAR with Shively's transmitter. Ex. 1009 at ¶¶ 63–64. *See* 37 C.F.R. § 42.65(a) ("Expert testimony that does not disclose the underlying facts or data on which the opinion is based is entitled to little or no weight."); *In re Am. Acad. of Sci. Tech Ctr.*, 367 F.3d 1359, 1368 (Fed. Cir. 2004) (explaining that "the Board has broad discretion" to weigh declarations and "conclude that the lack of factual corroboration warrants discounting the opinions expressed"); *Rohm & Haas Co. v. Brotech Corp.*, 127 F.3d 1089, 1092 (Fed. Cir. 1997) ("Nothing in the [federal] rules [of evidence] or in our jurisprudence requires the fact finder to credit the unsupported assertions of an expert witness."); *Ashland Oil, Inc. v. Delta Resins & Refractories, Inc.*, 776 F.2d 281, 294 (Fed. Cir. 1985) ("Lack of factual support for expert opinion going to factual determinations…may render the testimony of little probative value….").

By contrast, Dr. Short's declaration in support of this Patent Owner Response explains in detail why any arguable "increase" in PAR due to Shively's "spreading" scheme is trivial in view of Shively's drastic reduction in transmission signal power (which virtually eliminates clipping). *See* Ex. 2003 at ¶¶ 61–67.

Without any supporting calculations or data, and without even a qualitative discussion of what would constitute a problematic PAR, Petitioners' expert's declaration should not be given any weight. *See* 37 C.F.R. § 42.65(a).

3. Petitioners' Justification For Combining Shively And Stopler Uses The '158 Patent As A Roadmap And Suffers From Hindsight Bias

Petitioners allege that "[h]aving phase-aligned subcarriers causes a high peak-to-average power ratio (PAR), since all of the subcarriers add up coherently at the same time." Petition at p. 15. Yet, as admitted by Petitioners' expert, this is not mentioned or even alluded to in Shively or Stopler. Ex. 2002 at 14:2–15 and 97:6–18. Actually, out of all the evidence in this *inter partes* review, only the inventor of the '158 patent recognized the problem of high PAR due to phase-aligned carriers.

Besides the say-so of Petitioners' expert, the ***only cited evidence***—that high PAR results from transmitting the same data on multiple carriers—***is from the '158 patent***. Petition at p. 15; Ex. 1009 at ¶ 64. Here, Petitioners quite literally use the '158 patent as a roadmap for arriving at their theory of obviousness. This is a textbook case of impermissible hindsight bias. *See KSR Int'l Co. v. Teleflex Inc.*, 550 U.S. 398, 421 (2007) ("A factfinder should be aware, of course, of the distortion caused by hindsight bias and must be cautious of arguments reliant upon *ex post* reasoning."); *Insite Vision Inc. v. Sandoz, Inc.*,

783 F.3d 853, 859 (Fed. Cir. 2015) ("Defining the problem in terms of its solution reveals improper hindsight in the selection of the prior art relevant to obviousness.") (quoting *Monarch Knitting Mach. Corp. v. Sulzer Morat GmbH*, 139 F.3d 877, 881 (Fed. Cir. 1998)); *Texas Instruments Inc. v. Vantage Point Tech., Inc.*, IPR2014-01105, Paper No. 8 at p. 17 (P.T.A.B. January 5, 2015) ("This is an impermissible use of the '750 patent's description of the invention as a roadmap to piece together the prior art.") (citing *InTouch Technologies, Inc. v. VGO Commc'ns, Inc.*, 751 F.3d 1327, 1351 (Fed. Cir. 2014)).

4. There Is No Need To Solve Shively's Non-Existent PAR Problem

Petitioners state: "Since a high PAR brings numerous disadvantages, a POSITA would have sought out an approach to reduce the PAR of Shively's Transmitter." Petition at p. 15. As discussed in § IV.A, however, Shively does not present a problem with PAR. Because Shively does not disclose a system with a PAR problem, one having ordinary skill in the art would have had no reason to look for a solution. *See Runway Safe LLC v. Engineered Arresting Systems*, IPR2015-01921, Paper No. 9 at p. 11 (P.T.A.B. February 29, 2016) ("[W]e are not persuaded that a non-uniformity problem exists with Angley '025's cellular concrete system, and Petitioner has not provided adequate proof on that issue. Therefore, we are not persuaded by Petitioner's rationale for why a person of ordinary skill in the art would have replaced Angley '025's cellular

concrete blocks with ceramic foam.”).

5. Stopler Does Not Reduce PAR In A Multicarrier Transmitter

Petitioners incorrectly argue that “Stopler provides a solution for reducing the PAR of a multicarrier transmitter.” Petition at p. 15. As discussed in § IV.B, Stopler does not reduce PAR because phase scrambling is performed from symbol-to-symbol and not from carrier-to-carrier.

6. Stopler And Shively Could Not Be Combined

Without any supporting explanation, Petitioners baselessly claim that “[c]ombining Stopler’s phase scrambler into Shively’s transmitter would have been a relatively simple and obvious solution to reduce Shively’s PAR.” Petition at p. 16. This is wrong. Quite the opposite; Shively and Stopler are incompatible.

It would not be possible to incorporate Shively’s bit-spreading concept into Stopler. While Shively shows a point-to-point system (one transmitter and one receiver), Stopler teaches a point-to-multipoint system (one transmitter and multiple receivers). Figure 4 of Stopler is illustrative:

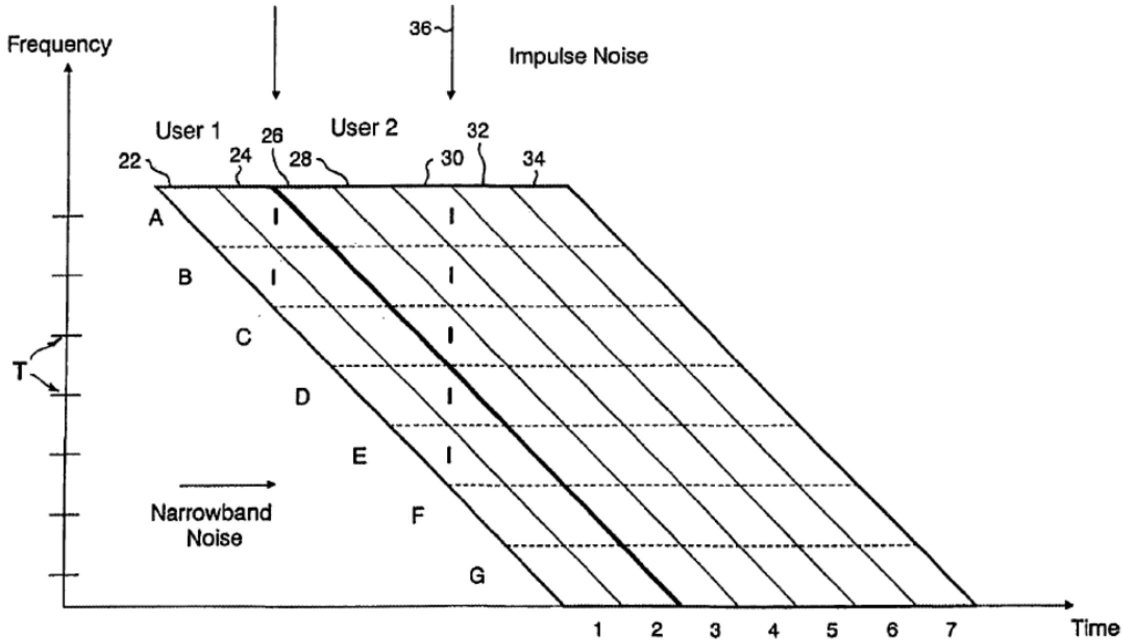
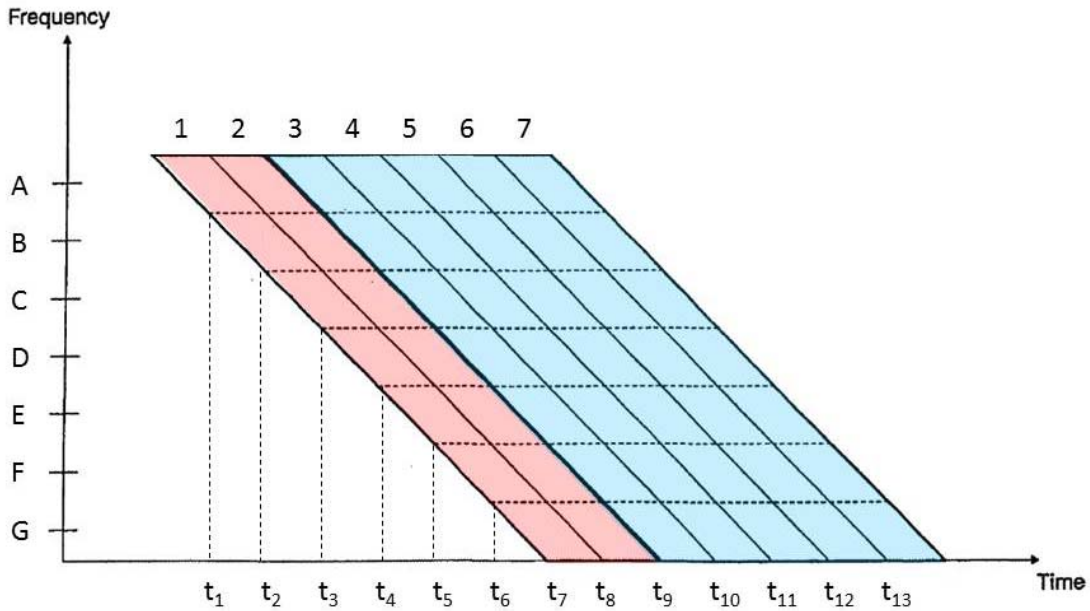


FIG. 4

See Ex. 2003 at ¶ 91.

In Stopler's point-to-multipoint example, User 1 receives data in diagonals 1 and 2, while User 2 receives data in diagonals 3–7. Ex. 1012 at 8:36–39 ("In the illustrated example, the data packet for User 1 consists of two diagonals 22, 24, while the data packet for User 2 consists of five diagonals, 26, 28, 30, 32 and 34."). This is depicted in a modified version of Figure 4 below where User 1's data is shown in red and User 2's data is shown in blue:

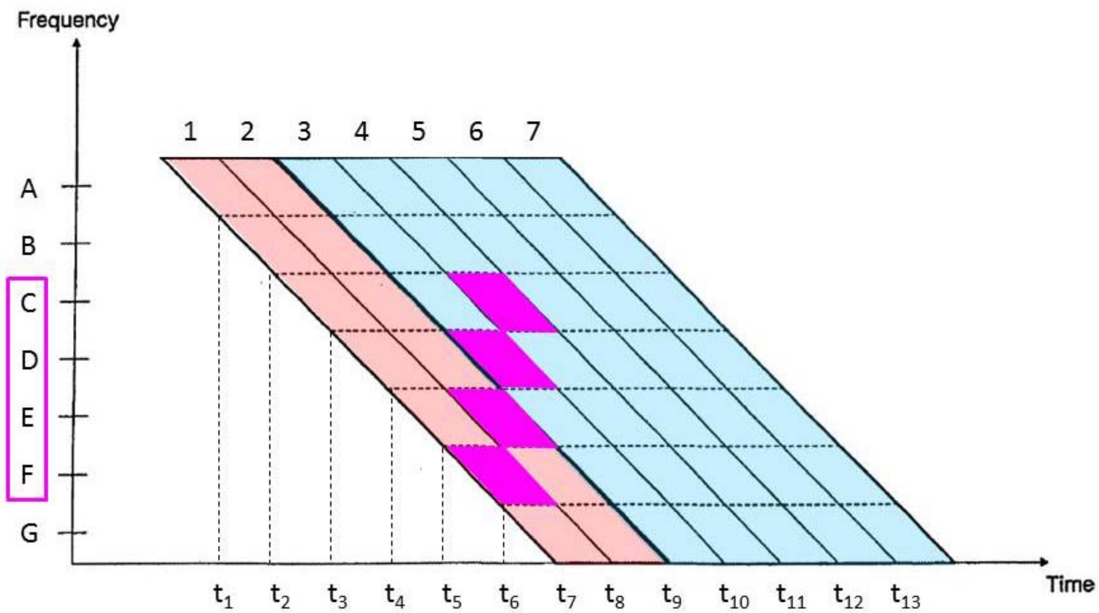


See Ex. 2003 at ¶ 92.

Also depicted in the illustration above along the horizontal time axis are times (t_1–t_{13}) at which successive multicarrier symbols are transmitted. Each symbol includes carriers A–G as illustrated along the vertical frequency axis, however, unlike a point-to-point multicarrier system, at t_1, only carrier A is intended for User 1; at t_2, only carriers A and B are intended for User 1; at t_3, only carriers B and C are intended for User 1 while carrier A is now intended for User 2, and so on. Stopler refers to this technique as "diagonalization." Ex. 1012 at 6:20–22 ("FIG. 4 is an illustration of diagonalization in accordance with the present invention for multitone data transmission as a function of time."). *See* Ex. 2003 at ¶ 93.

If one were to attempt to combine Stopler with Shively's bit-spreading,

multiple carriers must be used. Using Shively's example of four carriers, assume carriers C, D, E, and F, are used for bit-spreading. These carriers are highlighted in the pink rectangle:



See Ex. 2003 at ¶ 94.

Taking the example of a multicarrier symbol transmitted at time t_6, a spread bit over four carriers C–F (pink rhombuses), the spread bit would cross over from User 1 data to User 2 data. So part of the spread bit would be received by User 1 and not User 2, and conversely, the remaining part of the spread bit would be received by User 2 and not User 1. Because all of the bit-spreading carriers are not received by the same user, it would be impossible for User 1's or User 2's receiver to reconstruct the bit. *See* Ex. 2003 at ¶ 95.

Additionally complicating the combination of Shively and Stopler is that

the data intended for User 1 is different than the data intended for User 2. And further, the attenuation/noise characteristics for the communication channel to User 1 may be different from that of User 2. Thus, it would be unduly complex, if not impossible to keep track of what carriers to use for Shively's spreading. In other words, Shively's technique will not work with Stopler. Even Petitioners' expert, under cross-examination, admitted that Shively and Stopler are incompatible. Ex. 2002 at p. 144:22–145:1 ("Somebody learning the teachings of Shively working in the DSL space would not attempt to marry Shively with a system that each QAM signal goes into a different DMT symbol and has huge latency."); *see, more generally, id.* at 138:24–145:1. *See* Ex. 2003 at ¶ 96.

7. There Were No "Market Forces" In Effect To Prompt The Combination Of Shively's And Stopler's Techniques

Again without support or explanation, Petitioners rely on the following vague and conclusory justification for combining Shively and Stopler: "***Market forces*** would have prompted the development of multicarrier communications devices, such as Digital Subscriber Line (DSL) modems, employing both redundant bit transmission and phase scrambling." Petition at p. 16 (emphasis added). Petitioners and their expert, however, do not identify or explain such "market forces." The Petition and the supporting declaration do not identify a single product or standard that employs any of the ideas disclosed in Shively or

Stopler.

Nor was Petitioners' expert, upon questioning, aware of any product or standard that uses Shively's spreading concept:

> Q. Okay. But let's focus on the Shively spreading technique that you referenced in your declaration which is taking a single bit and spreading it across multiple carriers.
>
> A. So in the context of repeating 1 bit, 1 or more bits little m or more times, do I know of any product that uses that concept?
>
> Q. Correct.
>
> A. I can't recall.
>
> Q. Okay. And can you think of any standard that uses that technique?
>
> A. No. The DSL standards will be useful. It will be a useful application for DSL type loops but I don't know if any of them actually uses Shively's ideas.
>
> Q. But of all those DSL standards, you're not aware of any of them using Shively's spreading technique?
>
> A. I don't know of any of them.
>
> Q. So the answer is no?
>
> A. No.

Ex. 2002 at 135:11–136:1; *see, more generally, id.* at 134:24–137:16.

Without any evidence that Shively's transmitter ever existed, Petitioners' argument regarding "market forces" makes no sense. Petitioners allege that it would have been obvious to modify Shively's transmitter (*i.e.*, the base product) by adding Stopler's phase scrambler. Petition at p. 16; Ex. 1009 at ¶ 68. But how

would "market forces" apply when there is no evidence that Shively's transmitter—the base product—existed? Surely, there must be a "market" in order for "market forces" to apply.

When asked about his testimony regarding Shively and "market forces," Petitioners' expert acknowledged that his opinion was speculative:

> Q. What's your basis for suggesting that Shively's technique would be motivated by market forces, then?
>
> * * *
>
> A. I ***believe*** it's good technology. It's a good idea. I would ***believe*** some people ***would have*** tried it or used it. It's a good technology for subchannels that don't have enough signal to get a bit across. It repeats across multiple subchannels, make sure you scramble afterwards.

Ex. 2002 at 137:24–138:9 (emphasis added).

Without any evidence that there was a market for Shively's concept before the invention of the '158 patent (or ever), the notion that market forces would have prompted the modification of Shively's transmitter is meaningless. Petitioners' expert's declaration, therefore, is baseless, and the Petition is fact-free. *See* 37 C.F.R. § 42.65(a) ("Expert testimony that does not disclose the underlying facts or data on which the opinion is based is entitled to little or no weight.").

B. Stopler Does Not Disclose Phase Scrambling

Claim 1 recites "scrambling the phase characteristics of the carrier signals."

As discussed above in § III.C, this term should be construed to mean "adjusting the phases of a plurality of carriers in a single multicarrier symbol by pseudo-randomly varying amounts."

Petitioners incorrectly allege that Stopler discloses this type of phase scrambling: "It would have been obvious to a POSITA that modulating the phase-scrambled QAM symbols results in the phases of the carrier signals being correspondingly scrambled." Petition at p. 22. *See also* Ex. 1009 at p. 41–42 ("Stopler describes a 'phase scrambler' that scrambles the phase characteristics of the data symbols that are subsequently provided to a modulator for signal modulation on to the carrier frequencies.").

As discussed above in § IV.B, however, Stopler only discloses scrambling phases from one symbol to the next symbol in time, and not with respect to multiple carriers in a single multicarrier symbol. Because Stopler must be compatible with single-carrier CDMA, it makes no sense to argue that his phase scrambling must be performed within a single multicarrier symbol.

Because Stopler does not disclose phase scrambling as claimed in the '158 patent, Petitioners have not demonstrated by a preponderance of evidence that independent claim 1 is unpatentable. And accordingly, Petitioners' assertion of unpatentability for the dependent claims (2–14) also falls short.

C. Petitioners Explanation For Combining Bremer With Shively Or Stopler Lacks A Rational Basis

Petitioner fails to allege a legally sufficient rationale for combining Bremer's single-carrier privacy modem system, and for modifying it such that it would have been compatible, with Shively's and/or Stopler's multicarrier schemes. Claim 6 of the '158 patent recites "independently deriving the values associated with each carrier using a second pseudo-random number generator in the second transceiver." Accordingly, this claim requires the use of a second pseudo-random number generator for independently deriving the values used to scramble the carriers of the multicarrier signal. Petitioners acknowledge that Shively and Stopler do not disclose this and instead rely on Bremer. Petition at pp. 44–47. Petitioners also rely on the same combination of Bremer, Shively, and Stopler for claim 15 of the '158 patent. *Id.* at pp. 48–49.

But Petitioners' justification for combining these three very different references is conclusory and provides no explanation of why or how such a hypothetical combination would have been made. Instead, Petitioners merely allege:

> Although Bremer describes a single-carrier communication system, it would have been obvious to a POSITA that Bremer's teaching of a complementary pseudorandom number generator, and performing complementary changes on the received signal, would be equally applicable to the multicarrier systems of Shively and Stopler. Ex. 1009, p. 81. Because Stopler's multicarrier transmitter determines (as analyzed above in portions [1.5] and [1.6]) a phase shift for each

> carrier signal based on a value determined by a pseudo-random number generator, it would have been obvious to a POSITA that a compatible multicarrier receiver would include a second pseudo-random number generator whose output values determine a complementary phase shift for each carrier signal.

Petition at pp. 46–47. This allegation, however, presents more questions than it answers. For example, why would Bremer's single-carrier teachings be "equally applicable" to multicarrier systems? As another example, why "would [it] have been obvious to a POSITA that a compatible multicarrier receiver would include a second pseudo-random number generator"?

Petitioners' expert's declaration provides no additional guidance and only states: "Although Bremer describes a single-carrier QAM communication system, it would have been obvious to a POSITA that Bremer's teaching of a complementary pseudo-random number generator, and performing complementary changes on the received signal, could be applied on a carrier-by-carrier basis to the multicarrier system of Stopler." Ex. 1009 at p. 81. This statement provides no rationale whatsoever. It merely argues that Bremer's single-carrier scheme "could be applied" without further explanation, and is, therefore, without rational basis.

Because claims 7–13 depend from claim 6, and claims 21–28 and 30 depend from claim 20, Petitioners have not satisfied their burden for proving invalidity of these dependent claims as well.

VI. CONCLUSION

For at least the foregoing reasons, TQ Delta respectfully requests that the Board find that Petitioners have not established that any challenged claim is unpatentable.

Dated: February 24, 2017

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CUSTOMER NUMBER: 23446

CERTIFICATE OF WORD COUNT

I hereby certify that this Preliminary Patent Owner Response complies with the word count limit of 37 CFR §42.42. The word count, including footnotes, is approximately 11,500 words as measured by Microsoft Word.

CERTIFICATE OF SERVICE

I hereby certify that the Patent Owner Preliminary Response to Petition for *Inter Partes* Review Pursuant to 35 U.S.C. §§ 42.107 in connection with *Inter Partes* Review Case IPR2016-01020 was served on this 24th day of February, 2017 by electronic mail to the following:

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Paper 18
Entered: April 3, 2017

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

COMCAST CABLE COMMUNICATIONS, LLC,
COX COMMUNICATIONS, INC.,
TIME WARNER CABLE ENTERPRISES LLC,
VERIZON SERVICES CORP., and ARRIS GROUP, INC.,
Petitioner,

v.

TQ DELTA, LLC,
Patent Owner.

Case IPR2017-00417
Patent 8,718,158 B2

Before SALLY C. MEDLEY, KALYAN K. DESHPANDE, and TREVOR M. JEFFERSON, *Administrative Patent Judges*.

MEDLEY, *Administrative Patent Judge*.

DECISION
Institution of *Inter Partes* Review
37 C.F.R. § 42.108

Petitioner's Motion for Joinder
37 C.F.R. § 42.122(b)

I. INTRODUCTION

Comcast Cable Communications, L.L.C., Cox Communications, Inc., Time Warner Cable Enterprises L.L.C., Verizon Services Corp., and ARRIS Group, Inc. (collectively "Petitioner") filed a Petition for *inter partes* review of claims 1–30 of U.S. Patent No. 8,718,158 B2 (Ex. 1001, "the '158 patent"). Paper 1 ("Pet."). Concurrently with its Petition, Petitioner filed a Motion for Joinder with *Cisco Systems, Inc. v. TQ Delta, LLC*, Case IPR2016-01021 ("the Cisco IPR"). Paper 3 ("Mot."). Petitioner represents that the petitioners in the Cisco IPR—Cisco Systems, Inc. and DISH Network, L.L.C.[1]—do not oppose the Motion for Joinder. Mot. 1. TQ Delta, LLC ("Patent Owner") submits that it does not oppose joinder. *See* Paper 9. Patent Owner also elected to waive its Preliminary Response. *Id.*

For the reasons explained below, we institute an *inter partes* review of claims 1–30 of the '158 patent and grant Petitioner's Motion for Joinder.

II. RELATED PROCEEDINGS

Petitioner and Patent Owner identify several pending judicial matters as relating to the '158 patent. Pet. 2–3; Mot. 2–3; Paper 6, 2–4.

[1] DISH Network, L.L.C., who filed a Petition in IPR2017-00255, has been joined as a petitioner in the Cisco IPR.

In the Cisco IPR, we instituted an *inter partes* review of claims 1–30 of the ’158 patent on the following grounds:

References	Basis	Claims
Shively[2] and Stopler[3]	§ 103(a)	1, 2, 4, 15, 16, and 18
Shively, Stopler, and Gerszberg[4]	§ 103(a)	3, 5, 14, 17, 19, and 28–30
Shively, Stopler, and Bremer[5]	§ 103(a)	6, 9, 10, 12, 20, 23, 24, and 26
Shively, Stopler, Bremer, and Gerszberg	§ 103(a)	8, 11, 13, 22, 25, and 27
Shively, Stopler, Bremer, and Flammer[6]	§ 103(a)	7 and 21

Cisco Systems, Inc. v. TQ Delta, LLC, Case IPR2016-01021, slip op. at 20–21 (PTAB Nov. 4, 2016) (Paper 7) (“Cisco Dec.”).

III. INSTITUTION OF *INTER PARTES* REVIEW

The Petition in this proceeding asserts the same grounds of unpatentability as the ones on which we instituted review in the Cisco IPR. *Compare* Pet. 13–62, *with* Cisco Dec. 20–21. Indeed, Petitioner contends that the Petition asserts only the grounds that the Board instituted in the Cisco IPR, there are no new arguments for the Board to consider, and Petitioner relies on the same exhibits and expert declaration as the Cisco IPR. Mot. 6.

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[2] U.S. Patent No. 6,144,696; issued Nov. 7, 2000 (Ex. 1011) (“Shively”).
[3] U.S. Patent No. 6,625,219 B1; issued Sept. 23, 2003 (Ex. 1012) (“Stopler”).
[4] U.S. Patent No. 6,424,646 B1; issued July 23, 2002 (Ex. 1013) (“Gerszberg”).
[5] U.S. Patent No. 4,924,516; issued May 8, 1990 (Ex. 1017) (“Bremer”).
[6] U.S. Patent No. 5,515,369; issued May 7, 1996 (Ex. 1019) (“Flammer”).

For the same reasons set forth in our institution decision in the Cisco IPR, we determine that the information presented in the Petition shows a reasonable likelihood that Petitioner would prevail in showing that (a) claims 1, 2, 4, 15, 16, and 18 would have been obvious over Shively and Stopler, (b) claims 3, 5, 14, 17, 19, and 28–30 would have been obvious over Shively, Stopler, and Gerszberg, (c) claims 6, 9, 10, 12, 20, 23, 24, and 26 would have been obvious over Shively, Stopler, and Bremer, (d) claims 8, 11, 13, 22, 25, and 27 would have been obvious over Shively, Stopler, Bremer, and Gerszberg, and (e) claims 7 and 21 would have been obvious over Shively, Stopler, Bremer, and Flammer. *See* Cisco Dec. 7–20. Accordingly, we institute an *inter partes* review on the same grounds as the ones on which we instituted review in the Cisco IPR. We do not institute *inter partes* review on any other grounds.

IV. GRANT OF MOTION FOR JOINDER

The Petition and Motion for Joinder in this proceeding were accorded a filing date of December 5, 2016. *See* Paper 5. Thus, Petitioner's Motion for Joinder is timely because joinder was requested no later than one month after the institution date of the Cisco IPR, i.e., November 4, 2016.[7] *See* 37 C.F.R. § 42.122(b).

The statutory provision governing joinder in *inter partes* review proceedings is 35 U.S.C. § 315(c), which reads:

> If the Director institutes an inter partes review, the Director, in his or her discretion, may join as a party to that inter partes review any person who properly files a petition under section

[7] Because December 4, 2016 fell on a Sunday, the one-month date extended to the next business day, December 5, 2016. *See* 37 C.F.R. § 1.7.

> 311 that the Director, after receiving a preliminary response under section 313 or the expiration of the time for filing such a response, determines warrants the institution of an inter partes review under section 314.

A motion for joinder should (1) set forth reasons why joinder is appropriate; (2) identify any new grounds of unpatentability asserted in the petition; (3) explain what impact (if any) joinder would have on the trial schedule for the existing review; and (4) address specifically how briefing and discovery may be simplified. *See Kyocera Corp. v. Softview LLC*, Case IPR2013-00004, slip op. at 4 (PTAB Apr. 24, 2013) (Paper 15).

As noted, the Petition in this case asserts the same unpatentability grounds on which we instituted review in the Cisco IPR. *See* Mot. 6. Petitioner also relies on the same prior art analysis and expert testimony submitted by the Cisco Petitioner. *See id.* Indeed, the Petition is nearly identical to the petition filed by the Cisco Petitioner with respect to the grounds on which review was instituted in the Cisco IPR. *See id.* Thus, this *inter partes* review does not present any ground or matter not already at issue in the Cisco IPR.

If joinder is granted, Petitioner anticipates participating in the proceeding in a limited capacity absent termination of the Cisco Petitioner as a party. *Id.* at 7. Petitioner agrees to "assume a limited 'understudy' role" and "would only take on an active role if Cisco were no longer a party to the IPR." *Id.* Petitioner further represents that it "presents no new grounds for invalidity and its presence in the proceedings will not introduce any additional arguments, briefing or need for discovery." *Id.* Because Petitioner expects to participate only in a limited capacity, Petitioner submits that joinder will not impact the trial schedule for the Cisco IPR. *Id.* at 6–7.

We agree with Petitioner that joinder with the Cisco IPR is appropriate under the circumstances. Accordingly, we *grant* Petitioner's Motion for Joinder.

V. ORDER

Accordingly, it is:

ORDERED that an *inter partes* review is instituted in IPR2017-00417;

FURTHER ORDERED that the Motion for Joinder with IPR2016-01021 is *granted*, and Comcast Cable Communications, L.L.C., Cox Communications, Inc., Time Warner Cable Enterprises L.L.C., Verizon Services Corp., and ARRIS Group, Inc. are joined as a petitioner in IPR2016-01021;

FURTHER ORDERED that IPR2017-00417 is terminated under 37 C.F.R. § 42.72, and all further filings shall be made only in IPR2016-01021;

FURTHER ORDERED that, subsequent to joinder, the grounds for trial in IPR2016-01021 remain unchanged;

FURTHER ORDERED that, subsequent to joinder, the Scheduling Order in place for IPR2016-01021 (Paper 8) remains unchanged;

FURTHER ORDERED that in IPR2016-01021, the Cisco Petitioner and Petitioner will file each paper, except for a motion that does not involve the other party, as a single, consolidated filing, subject to the page limits set forth in 37 C.F.R. § 42.24, and shall identify each such filing as a consolidated filing;

FURTHER ORDERED that for any consolidated filing, if Petitioner wishes to file an additional paper to address points of disagreement with the

Cisco Petitioner, Petitioner must request authorization from the Board to file a motion for additional pages, and no additional paper may be filed unless the Board grants such a motion;

FURTHER ORDERED that the Cisco Petitioner and Petitioner shall collectively designate attorneys to conduct the cross-examination of any witness produced by Patent Owner and the redirect of any witness produced by the Cisco Petitioner and Petitioner, within the timeframes set forth in 37 C.F.R. § 42.53(c) or agreed to by the parties;

FURTHER ORDERED that the Cisco Petitioner and Petitioner shall collectively designate attorneys to present at the oral hearing, if requested and scheduled, in a consolidated argument;

FURTHER ORDERED that the case caption in IPR2016-01021 shall be changed to reflect joinder of Comcast Cable Communications, L.L.C., Cox Communications, Inc., Time Warner Cable Enterprises L.L.C., Verizon Services Corp., and ARRIS Group, Inc. as a petitioner in accordance with the attached example; and

FURTHER ORDERED that a copy of this Decision shall be entered into the record of IPR2016-01021.

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UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CISCO SYSTEMS, INC., DISH NETWORK, LLC,
COMCAST CABLE COMMUNICATIONS, LLC,
COX COMMUNICATIONS, INC.,
TIME WARNER CABLE ENTERPRISES LLC,
VERIZON SERVICES CORP., and ARRIS GROUP, INC.,
Petitioner,

v.

TQ DELTA, LLC,
Patent Owner.

Case IPR2016-01021[1]
Patent 8,718,158 B2

[1] DISH Network, L.L.C., who filed a Petition in IPR2017-00255, and Comcast Cable Communications, L.L.C., Cox Communications, Inc., Time Warner Cable Enterprises L.L.C., Verizon Services Corp., and ARRIS Group, Inc., who filed a Petition in IPR2017-00417, have been joined in this proceeding.

Paper No. __

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CISCO SYSTEMS, INC., DISH NETWORK, LLC,
COMCAST CABLE COMMUNICATIONS, LLC,
COX COMMUNICATIONS, INC.,
TIME WARNER CABLE ENTERPRISES LLC,
VERIZON SERVICES CORP., and ARRIS GROUP, INC.,
Petitioner,[1]

v.

TQ DELTA, LLC,
Patent Owner.

IPR No. IPR2016-01021
U.S. Patent No. 8,718,158 B2

PETITIONER'S REPLY

[1] DISH Network, L.L.C., who filed a Petition in IPR2017-00255, and Comcast Cable Communications, L.L.C., Cox Communications, Inc., Time Warner Cable Enterprises L.L.C., Verizon Services Corp., and ARRIS Group, Inc., who filed a Petition in IPR2017-00417, have been joined in this proceeding.

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Petitioner's Exhibit List

June 8, 2016

Ex. 1001	U.S. Patent No. 8,718,158 to Tzannes ("the '158 patent")
Ex. 1002	Prosecution File History of U.S. Pat. No. 8,718,158
Ex. 1003	Prosecution File History of U.S. Pat. No. 8,090,008
Ex. 1004	Prosecution File History of U.S. Pat. No. 7,769,104
Ex. 1005	Prosecution File History of U.S. Pat. No. 7,471,721
Ex. 1006	Prosecution File History of U.S. Pat. No. 7,292,627
Ex. 1007	Prosecution File History of U.S. Pat. No. 6,961,369
Ex. 1008	U.S. Provisional Application No. 60/164,134
Ex. 1009	Declaration of Dr. Jose Tellado under 37 C.F.R. § 1.68
Ex. 1010	Curriculum Vitae of Dr. Jose Tellado
Ex. 1011	U.S. Patent No. 6,144,696 to Shively et al. ("Shively")
Ex. 1012	U.S. Patent No. 6,625,219 to Stopler ("Stopler")
Ex. 1013	U.S. Patent No. 6,424,646 to Gerszberg et al. ("Gerszberg")
Ex. 1014	Harry Newton, NEWTON'S TELECOM DICTIONARY, 13th Ed. (1998) (selected pages)
Ex. 1015	Kim Maxwell, "Asymmetric Digital Subscriber Line: Interim Technology for the Next Forty Years," *IEEE Communications Magazine* (Oct. 1996).
Ex. 1016	Walter Goralski, ADSL AND DSL TECHNOLOGIES (McGraw-Hill 1998) (selected pages)

Ex. 1017	U.S. Patent No. 4,924,516 to Bremer et al. ("Bremer")
Ex. 1018	American National Standard for Telecommunications, Network and Customer Installation Interfaces—Asymmetric Digital Subscribers Line (ADSL) Metallic Interface (ANSI T1.413-1995)
Ex. 1019	U.S. Patent No. 5,515,369 to Flammer, III et al. ("Flammer")
Ex. 1020	Declaration of David Bader
Ex. 1021	Fig. 6 from Ex. 2009 (T. Regan, "ADSL Line Driver/Receiver Design Guide, Part 1" (February 2000)).
Ex. 1022	Robert T. Short, "Physical Layer," *in* WIMEDIA UWB (2008).
Ex. 1023	Denis J. G. Mestdagh and Paul M. P. Spruyt, "A Method to Reduce the Probability of Clipping in DMT-Based Transceivers," *IEEE Transactions on Communications*, Vol. 44, No. 10, (October 1996).
Ex. 1024	Stefan H. Muller and Johannes B. Huber, "A Comparison of Peak Power Reduction Schemes for OFDM," IEEE Global Telecommunications Conference (1997).
Ex. 1025	Jose Tellado-Mourelo, "Peak to Average Power Reduction for Multicarrier Modulation," A dissertation submitted to the Department of Electrical Engineering and the Committee on Graduate Studies of Stanford University (Sept. 1999)
Ex. 1026	Second Declaration of Dr. Jose Tellado under 37 C.F.R. § 1.68
Ex. 1027	Deposition Transcript of Dr. Robert T. Short
Ex. 1028	T. Starr, J. M. Cioffi, P. J. Silverman, UNDERSTANDING DIGITAL SUBSCRIBER LINE TECHNOLOGY (1999) (selected pages).
Ex. 1029	Abe, RESIDENTIAL BROADBAND (2000) (selected pages).
Ex. 1030	Mohamed Zekri, et al., "DMT Signals with Low Peak-to-Average Power Ratio," *Proceedings of the IEEE International Symposium on Computers and Communications* (held July 6-8, 1999).
Ex. 1031	Second Declaration of David Bader

Ex. 1032	Peter S. Chow, et al., "A Practical Discrete Transceiver Loading Algorithm for Data Transmission over Spectrally Shaped Channels", *IEEE Transactions on Communications*, Vol. 43, No. 2/3/4 (1995).
Ex. 1033	Kamran Sistanizadeh, et al., "Multi-Tone Transmission for Asymmetric Digital Subscriber Lines (ADSL)", *Communications, 1993. ICC '93 Geneva. Technical Program, Conference Record, IEEE International Conference* (held May 23-26, 1993)
Ex. 1034	ADSL transmitter simulation program by Dr. Tellado

I. Summary

Patent Owner TQ Delta raises various arguments, but they are all severely flawed, whether by a misinterpretation of the prior art or a misunderstanding of the technology involved. The obviousness rationale for combining Shively and Stopler derives almost entirely from a POSITA's straightforward consideration of undisputed facts. The only substantive limitation in dispute—"scrambling"—is plainly taught by Stopler, which even uses the same "scrambling" terminology to describe the concept. Accordingly, the Board should issue a Final Written Decision holding all claims of the '158 patent unpatentable for obviousness.

II. Claim Construction

A. "scrambling…a plurality of carrier phases"

TQ Delta proposes construing the phrase "scrambling…a plurality of carrier phases" to mean "adjusting the phases of a plurality of carriers in a single multicarrier symbol by pseudo-randomly varying amounts." Resp., pp.14-19.

The "scrambling" phrase does not need construction, since the prior art relied upon—Stopler—uses the same "phase scrambling" terminology to describe pseudo-random phase changes. CSCO-1012, 12:24-31. Accordingly, the Board should not adopt TQ Delta's proposed construction.

B. "transceiver"

TQ Delta notes that a district court—which applies a different claim

interpretation standard—adopted a different claim construction for "transceiver." Resp., pp.13-14. But TQ Delta does not show any error in the Board's currently-adopted construction. Accordingly, there is no reason for the Board to modify its construction.

III. Combining the teachings of Shively and Stopler would have been obvious to a POSITA

TQ Delta argues that it would not have been obvious to combine the DSL technologies of Shively and Stopler. Resp., pp.44-45. TQ Delta further alleges that Cisco's obviousness rationale suffers from hindsight bias. *Id.*, p.49. But the obviousness rationale is based on agreed-upon facts and common engineering sense. As discussed further below, there is no dispute that:

- multicarrier communication systems generate signals with a high peak-to-average power ratio (PAR), which is undesirable;
- repeating the same bits on multiple carriers, the technique taught in Shively, increases PAR;
- scrambling the phases of individual signal carriers was a known technique for reducing PAR; and
- Stopler teaches a phase scrambler.

In light of these facts, a POSITA would have found it obvious to incorporate a phase scrambler—like that in Stopler—into Shively's system to counteract the increase in PAR caused by Shively's bit spreading technique. CSCO-1009, ¶¶67-

68. Rather than hindsight, the combination would have been a straightforward application of ordinary engineering sense to basic facts known to a POSITA. CSCO-1009, ¶¶18, 67-68.

A. DMT-based communications systems were known to be susceptible to challenges caused by signals with high PAR

There is no dispute that multicarrier systems using discrete multitone ("DMT") technology faced issues relating to signals with a high peak-to-average ratio ("PAR"). *See* TQ-2003, ¶¶20-22. Similarly, there is no dispute that signals with high PAR can induce clipping in the transmitter circuitry. *See* TQ-2003, ¶¶24-25, 30. These facts are succinctly stated in the ANSI T1.413-1995 standard:

> A DMT time-domain signal ***has a high peak-to-average ratio*** (its amplitude distribution is almost Gaussian), and ***large values may be clipped*** by the digital-to-analog converter.

CSCO-1018, §6.5 (p.36).

Cisco's expert, Dr. Tellado, testified—and TQ Delta has not disputed—that a POSITA would have known such background information:

> [A]n understanding of the '158 patent requires… appreciation for the potential for such multicarrier signals to have a high peak-to-average ratio, causing clipping during transmission. Such knowledge would be within the level of skill in the art.

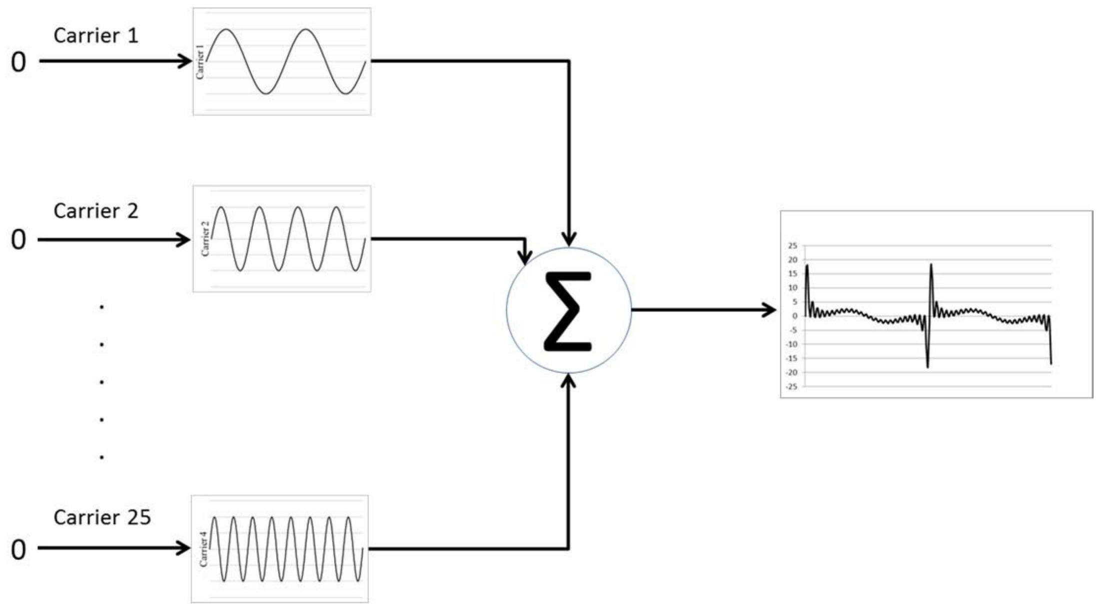
CSCO-1009, ¶18.

The parties also agree that engineers knew that one way to reduce the

likelihood of clipping was to design transmitters to handle a greater dynamic range. TQ-2003, ¶26. But it was also known that such transmitters were more expensive, less efficient, consumed more electricity, and generated more heat. TQ-2003, ¶26; CSCO-1027, 45:21-46:6. Thus, engineers would have sought out other techniques to reduce PAR. CSCO-1027, 46:23-47:3.

B. Transmitting the same data on multiple carriers causes a spike in signal amplitude and increases PAR

There is no dispute that when many carriers of a multicarrier signal have the same phase, the result is a signal with "large spikes in amplitude and, therefore, a high PAR." TQ-2003, ¶22. TQ Delta acknowledged that high PAR occurs "where the same bit or bits is/are purposely sent in a redundant manner on multiple carriers." Resp., pp. 6-7; TQ-2003, ¶22; CSCO-1027, 97:13-15. As TQ Delta's declarant Dr. Short illustrated in the figure below, when the signal carriers carry the same bits, they have the same phases, which add coherently to create a transmission signal with a large spike in amplitude. TQ-2003, ¶22. TQ Delta admitted that such signal has a "high PAR." Resp., p.7.



TQ-2003, ¶18.

C. Shively transmits the same data on multiple carriers, which increases PAR

In Shively's system the same bits are purposely sent in a redundant manner on multiple carriers, which TQ Delta admits leads to high PAR.[2] CSCO-1011, 11:17-18; Resp., p.10; CSCO-1027, 9:7-10. Because the same data (Shively's "k-bit symbol") is modulated on multiple carriers, the carriers will phase align and will add coherently to create a transmission signal with a spike in amplitude

[2] Elsewhere TQ Delta argues that Shively does not suffer from increased PAR (Resp., pp.47-49), but that argument is based on an erroneous analysis of a hypothetical 18,000-foot ADSL line. TQ Delta and its expert repeatedly concede that Shively transmits the same data on multiple carriers, which increases PAR. Resp., pp.10; TQ-2003, ¶22; CSCO-1027, 96:16-20, 97:10-15, 100:4-7.

(power). TQ-2003, ¶ 22; CSCO-1027, 97:21-23. This spike would not have occurred without Shively's technique, since the carriers would have been deemed unusable, and no data would have been transmitted on those carriers. CSCO-1026, ¶6. Thus, Shively's technique creates new amplitude spikes in the multicarrier signal and causes an increase in PAR. *Id*.; Resp., pp.6-7.

D. Phase scrambling was a known technique for reducing PAR

A POSITA would have known that one way to reduce PAR is to scramble phases of individual carriers. As Dr. Tellado stated, "phase scrambling was probably the most popular way" to reduce PAR. TQ-2002, 100:9:13; CSCO-1027, 9:11-13 ("just by rotating the symbols, then you can reduce the peak-to-average ratio.").

Prior art technical publications confirm that phase scrambling was a known way to reduce PAR. A 1996 article notes the use of "discrete multitone (DMT) modulation technique … for applications [such as] asymmetric digital subscriber line (ADSL)." CSCO-1023, p.1234; CSCO-1031, ¶2. The article describes prior efforts "to reduce the peak-to average power ratio of the DMT signal," and proposes a technique employing a "random phasor transformation." CSCO-1023, p.1234-35. Dr. Short agreed that such phasor transformations include phase scrambling. CSCO-1027, 77:18-20.

Another 1997 article notes that "it is highly desirable to reduce the PAR" of

a multicarrier signal. CSCO-1024, p.1; CSCO-1031, ¶3. To do so, the article describes a transmitter that "constructs its transmit signal with low PAR by coordinated addition of appropriately ***phase rotated signal parts***" where the signal parts are subcarriers within a multicarrier vector. CSCO-1024, p.1. This technique was applied to DMT systems, where the DMT tones (carriers) had a "phase rotation applied to each tone." CSCO-1028, p.238; CSCO-1031, ¶7.

Thus, prior to November 9, 1999 (the earliest claimed priority date of the '158 Patent), multiple engineers working with DMT-based systems had written about the use of phase scrambling to reduce PAR. These articles support Dr. Tellado's opinion that a POSITA would have been familiar with phase scrambling as a known technique for reducing PAR. CSCO-1004, ¶¶60, 67; CSCO-1026, ¶54.

TQ Delta presents no evidence to the contrary. While, TQ Delta's declarant Dr. Short agreed that randomizing phases of individual carriers is a way to reduce PAR, he pointedly declined to provide any opinion regarding the fact that phase scrambling was known in the prior art. CSCO-1027, 50:3-8, 51:4-11.

Thus, all of the evidence of record supports the unchallenged conclusion that a POSITA in the prior art timeframe would have been familiar with phase scrambling as a technique for reducing PAR in DMT systems.

E. Combining Stopler's phase scrambler with Shively's transmitter is merely the use of a known technique to improve a similar device.

TQ Delta argues that Cisco failed to sufficiently explain how the Shively and Stopler combination is the use of a known technique to improve a similar device in the same way. Resp., pp.45-47. Instead, TQ Delta argues that Cisco used hindsight bias to make the combination. Resp., pp.49-50. These assertions are unfounded.

First, the Petition unambiguously identified the "known technique" as Stopler's use of a phase scrambler to randomize the phases of subcarriers, which improves (reduces) PAR. Pet., p.14.

Second, the Petition explains that "[c]ombining Stopler's phase scrambler into Shively's transmitter would have been a relatively simple and obvious solution to reduce Shively's PAR." Pet., p.15. Thus, in the combination, the phase scrambler improves Shively's transmitter (by reducing PAR) in the same way that the phase scrambler improves Stopler's transmitter.

Finally, the Petition explains that Shively and Stopler describe similar devices, specifically, "multicarrier communications apparatuses, such as modems." Pet., p.17.

Thus, the combination is merely the use of a known technique (phase scrambling) to improve a similar device (multicarrier modem) in the same, known

way (to reduce PAR). CSCO-1009, ¶¶ 62-70.

F. Market forces would have prompted a POSITA to combine Shively and Stopler

TQ Delta argues that there were no "market forces" to prompt the combination of Shively's and Stopler's techniques." Resp., pp.55-57.

But the most basic of market forces—cost—was recognized at the time as influencing the development of multicarrier technology. Multiple engineers wrote of the importance of minimizing cost:

> **Cost** – This is the dominant factor when dealing with consumer markets.

CSCO-1029, p.70; CSCO-1031, ¶8.

> ***Success of a service*** (and its underlying technology) ***depends greatly on its price*** and its relation to available alternatives. Service price, in turn, depends greatly on the cost of equipment and labor costs for operation….

CSCO-1028, p.17.

As Dr. Short admitted, an increase in PAR is associated with more expensive communication equipment. CSCO-1027, 45:15-46:12. The drive to reduce equipment costs would have motivated a POSITA to include Stopler's phase scrambler in Shively's transmitter to reduce PAR. CSCO-1026, ¶54. Thus, combining Shively and Stopler would have been obvious for this additional reason.

IV. Stopler's phase scrambler reduces PAR because it scrambles phases of individual QAM symbols

TQ Delta argues that Stopler's phase scrambler does not reduce PAR because the phase scrambler is applied to DMT symbols, not to individual QAM symbols. *See* Resp., pp.14-18, 57-59.[3] But TQ Delta's argument is based on an illogical reading of Stopler and undermined by the testimony of its expert.

A. Dr. Short admitted that Stopler's phase scrambler is applied to QAM symbols

Stopler states that "the phase scrambler is applied to all symbols." CSCO-1012, 12:26-27. Dr. Short agreed that in this statement, Stopler refers to phase scrambling *QAM symbols*:

> A. …"However, to simplify implementation, the phase scrambler is applied to all symbols," not just the overhead symbols, so he is implying that he's rotating the entire bank of symbols.…
>
> Q. In that sentence, however, to simplify what you read --
>
> A. Yes.
>
> Q. -- it says it applies to all symbols, right?
>
> A. Correct.
>
> Q. ***And those symbols are QAM symbols***?
>
> A. ***Correct***.

[3] A DMT symbol comprises multiple signal carriers, and signal carriers are also referred to as QAM symbols.

CSCO-1027, 59:9-12, 60:15-22 (emphasis added).

More broadly, Stopler uses the word "symbol" multiple times in describing the phase scrambler, and Dr. Short agreed that these refer to *QAM symbols*:

> The input to the QAM mapper **82** is data in the form of m-tuples which are to be mapped into QAM symbols, for example, ranging from QPSK to 256-QAM, tone by tone. The constellation mapping may be the same as that used in ADSL. In order to randomize the overhead channel symbols, a phase scrambling sequence is applied to the output symbols. However, to simplify implementation, the phase scrambler is applied to all symbols, not just the overhead symbols. For example, the phase scrambling sequence may

CSCO-1027, 54:17-55:3.

CSCO-1027, 55:19-24.

CSCO-1027, 59:9-12 & 60:15-22.

CSCO-1012, 12:20-28 (annotated).

Furthermore, there is no dispute that the input to Stopler's phase scrambler is a sequence of QAM symbols. CSCO-1027, 58:6-8. Thus, there is no dispute that Stopler's phase scrambler takes in QAM symbols and applies phase scrambling to QAM symbols.

B. Stopler does not describe phase scrambling DMT symbols

TQ Delta's argument—that a POSITA would have understood Stopler as teaching the phase scrambling of DMT symbols—is illogical and has no basis in Stopler's text. Resp., p.34. Indeed, Dr. Short admitted that Stopler does *not* describe applying the phase scrambler to a DMT symbol:

> Q. Well, you would agree with me that [Stopler] doesn't

> expressly teach applying the phase scrambler to the DMT as a whole?
>
> A. I would agree with that.

CSCO-1027, 60:11-14.

Stopler states that the purpose of the phase scrambler is to "randomize the overhead channel symbols." CSCO-1012, 12:24. Since overhead channel symbols are QAM symbols (*see* CSCO-1027, 55:19-24), Stopler's intent is to randomize the phases of QAM symbols. Randomizing DMT symbols—as TQ Delta argues—would not achieve Stopler's stated purpose for the phase scrambler. CSCO-1026, ¶57.

The illogic of TQ Delta's argument is further demonstrated by the broader context of the phase scrambler in Stopler's system. CSCO-1026, ¶¶55-58. Stopler contemplates that the phase scrambler could be used with either a DMT *or* CDMA modulator. CSCO-1012, 12:55-57; *see also* Resp., pp.32-33. Since a CDMA modulator does not employ DMT symbols, there is no reason for Stopler's phase scrambler to operate on DMT symbols. CSCO-1026, ¶58. In contrast, both DMT and CDMA modulators employ QAM symbols. *Id*. Thus the straightforward reading of Stopler—as applying the phase scrambler to individual QAM symbols—is the only possible reading that is logically and technically coherent. *Id*.

C. Stopler contemplates systems with multiple pilot tones and multiple kinds of overhead channel symbols

TQ Delta argues that Stopler should be understood as phase scrambling DMT symbols because the phase scrambler's purpose is to randomize the overhead channel symbols, and each DMT symbol in the ANSI T1.413-1995 standard has only one pilot tone. Resp., p.40; *see* CSCO-1018, p.46. This argument fails for multiple reasons, including that it ignores the plain text of Stopler.

First, Stopler does not limit overhead channel symbols to a single pilot tone per DMT symbol. Indeed, Stopler refers elsewhere to multiple "pilot ***tones***." CSCO-1012, 12:51-52. Furthermore, Stopler's techniques are not limited to ANSI T1.413-1995 or even DMT, but are applicable to any "particular signal modulation desired." CSCO-1012, 12:56-57. As Dr. Short admitted, other multicarrier technologies can use more than one pilot tone. CSCO-1027, 61:15-18.

Second, pilot tones are just an *example* of overhead symbols. *See* CSCO-1012, 9:62 ("overhead signals, ***such as*** pilot tones") & 12:51-52 ("overhead bits (***e.g.***, pilot tones)") (emphases added). Many other kinds of overhead channel symbols are also possible. For example, the TIE/EIA-95 Standard referenced in Stopler describes multiple overhead channels that include one pilot channel, one sync channel and up to 9 paging channels. TQ-2005, pp.728-729; CSCO-1012, 12:61-63. Thus, the entire logic of TQ Delta's argument is based on the incorrect premise that Stopler assumed that the only overhead would be a single ANSI

T1.413-1995 pilot tone.

A POSITA would have understood that data in the overhead channel symbols will probably not be random, but is likely to be highly structured. CSCO-1009, p.24. In the ANSI T1.413-1995 standard, for example, the bits encoding the pilot tone are held constant at zero. CSCO-1018, p.64. Such non-random, structured data increases the likelihood for phases of carriers to align, thereby increasing PAR. CSCO-1009, ¶59. To break up the structured data, Stopler employs a phase scrambler that scrambled phases of overhead channel symbols, and thereby reduces PAR. CSCO-1009, ¶60; CSCO-1026, ¶¶57-58.

D. TQ Delta’s arguments about the ’156 patent are moot because it changes the phase of individual QAM symbols

TQ Delta argues that Stopler’s phase scrambler operates on DMT symbols because it is implementing a noise-immunity technique described in U.S.6,370,156. Resp., pp.38-40. This argument fails for several reasons.

First, TQ Delta does not offer any explanation for how Stopler, the inventor, would have learned of the noise-immunity technique in the ’156 patent, which was not published before it was granted in 2002. Thus, at the time of the Stopler patent’s filing in 1999, the inventor Stopler could not have known of the patent application that resulted in the ’156 patent.

Second, the ’156 patent does not scramble DMT symbols. Rather, the ’156 patent describes sequencing the pilot carrier—and only the pilot carrier—through

four different phase values. *See* TQ-2004, 7:5-6, 7:40-45. Dr. Short agreed that the '156 Patent rotates only the phase of the pilot carrier (tone), not the phase of an entire DMT symbol. CSCO-1027, 67:4-9.

Thus, not even the '156 patent describes changing the phase of an entire DMT symbol. Even if Stopler used the '156 patent's technique—and the evidence discussed below suggests that it does not—that fact would still not support TQ Delta's assertion that Stopler's phase scrambler is applied to DMT symbols.

Third, there are significant technical differences between Stopler's phase scrambler and the technique described in the '156 patent. The '156 patent changes the phase of only the pilot carrier. TQ-2004, 7:40-45; CSCO-1027, 67:4-9. Stopler's phase scrambler, however, is applied not just to the pilot tone, but to "all symbols." CSCO-1012, 12:26-28.

Stopler and the '156 patent also differ in their phase rotation sequences. The '156 patent changes its pilot carrier using a repeating sequence of four rotations. TQ-2004, 7:40-45; *see also* CSCO-1027, 76:24-77:5 (explaining that the '156 patent does not require random phase changes). Stopler, on the other hand, uses a "phase scrambling sequence… generated by a pseudo-random generator," making the phase changes effectively random. CSCO-1012, 12:28-29.

Thus, there is virtually no similarity between Stopler's phase scrambler and the '156 patent's technique, and therefore no reason to believe that Stopler's

description of the phase scrambler should be read as using ideas from the '156 patent. And even if it were, the '156 patent does not rotate the phase of entire DMT symbols, so there is no reason to disturb the natural reading of Stopler as applying its phase scrambler to QAM symbols.

V. TQ Delta's remaining arguments are without merit

TQ Delta raises a variety of additional arguments, none of which hold up to even moderate scrutiny.

A. Shively's technique is not limited to 18,000 foot cables

In support of its allegation that Shively's technique does not increase PAR, TQ Delta presents a supposed analysis of Shively's PAR for an 18,000 foot cable. Resp., pp.27-29. While that analysis is deeply flawed—as discussed below—the entire premise for looking at an 18,000 foot example is illusory. Shively is not limited to cable lengths of 18,000 feet. Shively merely mentions this length in passing as an example of where "high signal attenuation… is usually observed." CSCO-1011, 9:66-10:1. Notably, the T1.413-1995 standard defines multiple "test loops," including loops of ten, 6000, 9000, and 12000 feet. CSCO-1018, p.118; TQ-2002, 57:3-4 ("modems have to work with different lengths of loops, not only 18,000 feet").

TQ Delta's attempt to pigeonhole Shively's technique to 18,000-foot cables is also inconsistent with Shively's disclosure. Shively describes its bit-spreading

technique as a way to use "impaired parts of the frequency band," and to "compensate for high attenuation ***and/or high noise***" in such impaired subcarriers. CSCO-1011, 15:58-59, 15:50. Dr. Short admitted that other impairments—including crosstalk noise—occur on line lengths of less than 18,000 feet and agreed that Shively's technique could be used on lines with noise-induced impairments. CSCO-1027, 24:8-25:10, 93:11-94:8.

The ANSI T1.413-1995 standard describes crosstalk as potentially significant noise source in an ADSL system. There are many sources of crosstalk and relatively short lines can have significant crosstalk noise. CSCO-1026, ¶7. The ANSI standard provides multiple graphs showing the potential near-end cross talk ("NEXT") noise levels caused by various kinds of adjacent communication lines. As illustrated below, the NEXT noise levels are above the -140 dBm/Hz background noise floor:

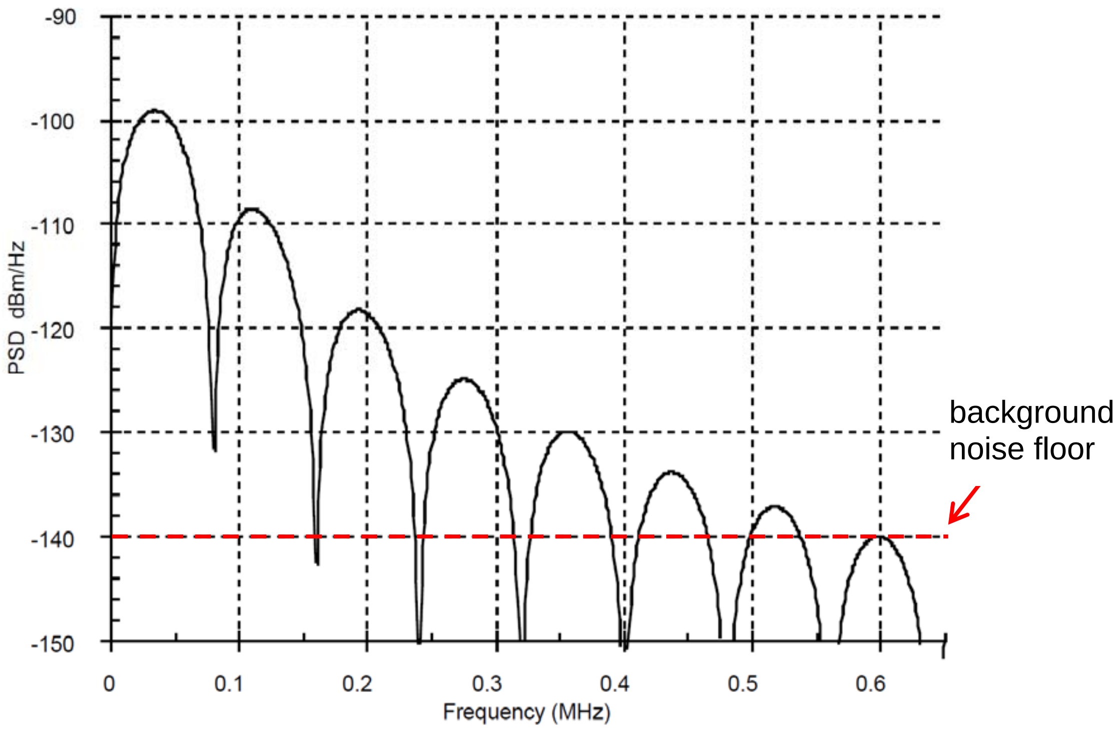


Figure B.1 – 24-disturber DSL NEXT

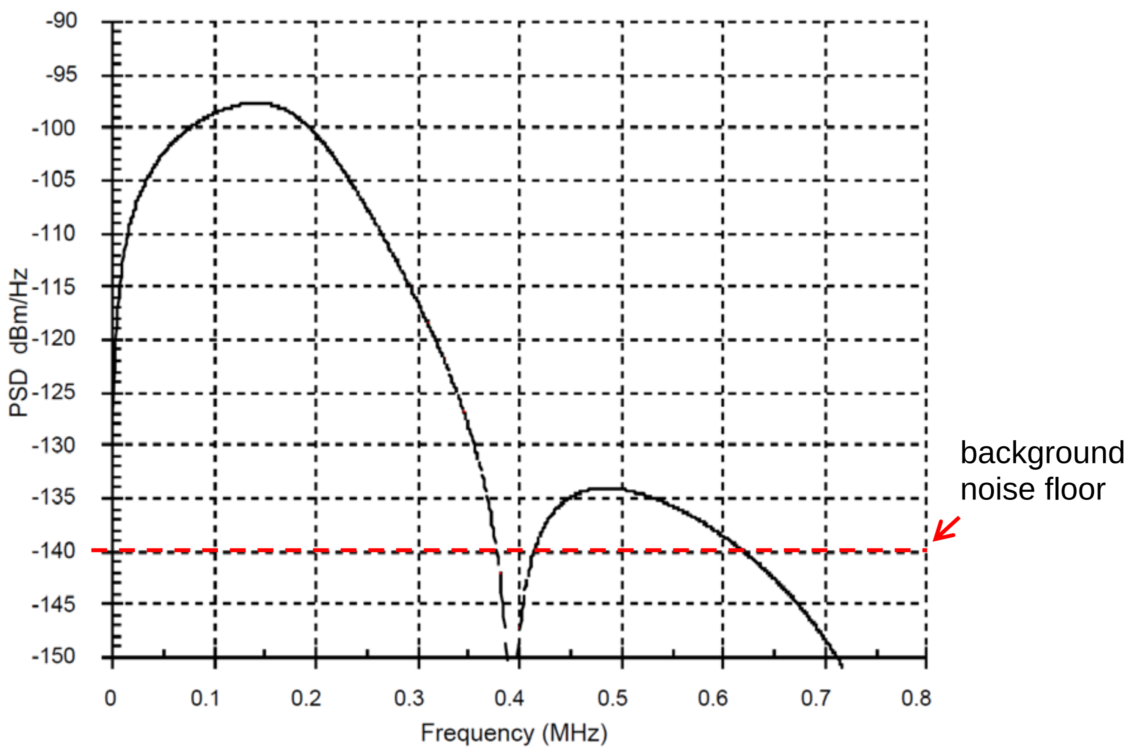


Figure B.2 – 10-disturber HDSL NEXT

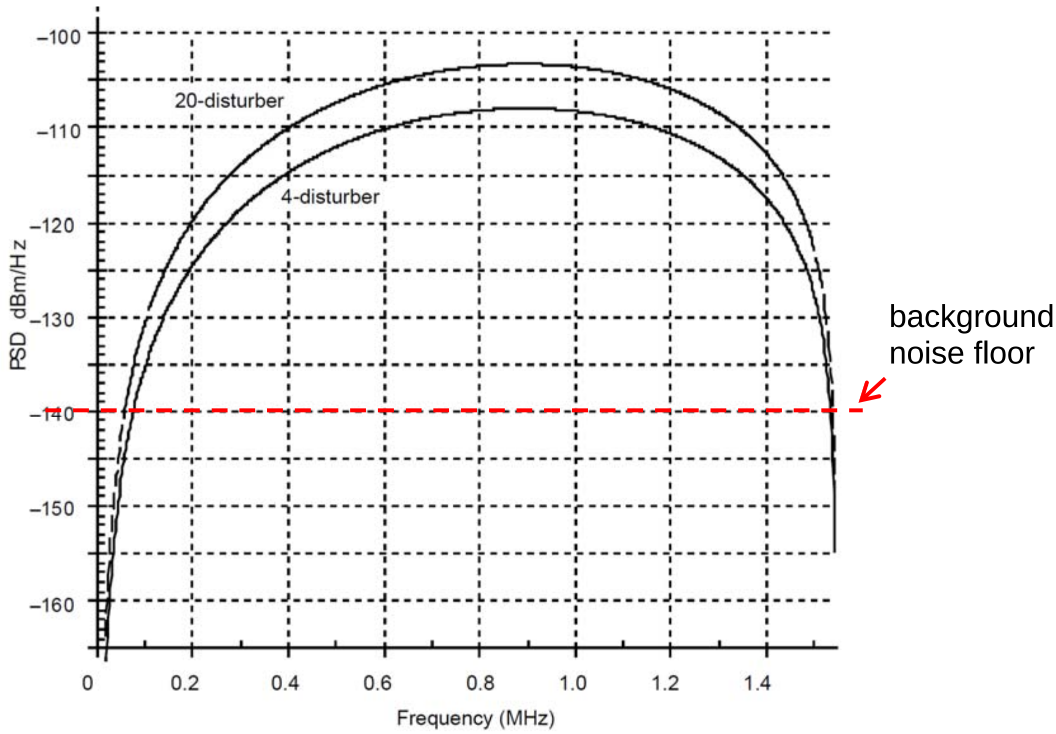


Figure B.3 – 4 and 20-disturber T1 NEXT

CSCO-1026, ¶¶9-11; CSCO-1018, pp.138, 140, 142.

The ANSI T1.413-1995 standard also provides an example graph showing potential far-end crosstalk in an ADSL system:

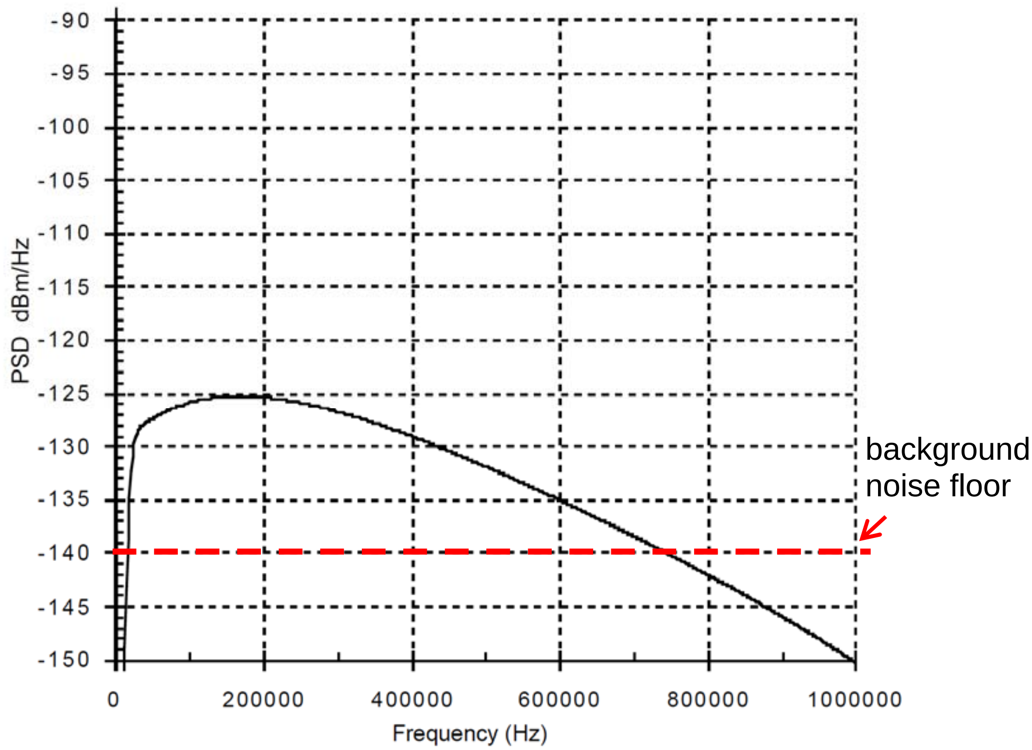


Figure B.4 – Theoretical 10-disturber ADSL FEXT

CSCO-1026, ¶12; CSCO-1018, p.144.

These graphs of crosstalk noise levels show that crosstalk noise can be a significant line impairment, with the crosstalk noise exceeding the -140 dB/Hz background noise level. CSCO-1026, ¶13. Because crosstalk can be significant on even short lines, Shively's technique could be usefully applied to any line length. CSCO-1026, ¶14. Accordingly, there is no basis for TQ Delta's attempt to limit Shively's technique to only 18,000-foot cables.

B. Dr. Short's analysis of a hypothetical 18,000 foot cable is flawed

Because Shively's technique is not limited to 18,000 foot cables, the entire premise of Dr. Short's supposed analysis of such an example is baseless. Further,

Dr. Short makes fundamentally incorrect assumptions that render his results untrustworthy and meaningless.

Specifically, Dr. Short assumes that a multicarrier signal is approximately Gaussian, *even when bits are repeated on multiple carriers*. TQ-2003, ¶66. This is a fundamental engineering error, since the Gaussian approximation only holds when the phases of the individual carriers are random. CSCO-1026, ¶16; CSCO-1030, p.362 ("The amplitude distribution of a DMT signal ***with random input data*** is approximately Gaussian for large number of carriers."); CSCO-1031, ¶4; CSCO-1001, 1:52-55. Shively's technique breaks that assumption because the bit-spreading subcarriers are purposely set to the same phase.

Because a system employing Shively's technique does not have carriers with random phases, the signals produced by such a system cannot be reasonably approximated by a Gaussian random variable. CSCO-1026, ¶16. The following examples demonstrate this fact and illustrate the enormous errors that resulted from Dr. Short's use of the approximation.

1. Likelihood of phase alignment for random data

In a multicarrier signal transmitting random data, the phase of each subcarrier is essentially random. If two carriers are phase-modulated with one bit per subcarrier, the likelihood of both bits being equal—and the carriers having the same phase—is 2 in 4:

Bit #1	Bit #2	Phases Aligned?
0	**0**	**Aligned**
0	1	Not aligned
1	0	Not aligned
1	**1**	**Aligned**

Thus, if the bits are random, the likelihood of the subcarriers having the same phase is 50%. CSCO-1026, ¶18. With four bits, the likelihood of four subcarriers having the same phase is 2 in 16, or 12.5%. CSCO-1026, ¶20. With 8 bits, the likelihood is 2 in 256, or 0.78%. CSCO-1026, ¶21. Generally, the likelihood of *n* subcarriers transmitting *n* random bits all having the same phase is:

$$\frac{2}{2^n} \qquad \text{Eq. 1}$$

CSCO-1026, ¶22.

2. Likelihood of phase alignment using Shively's bit-spreading technique

Shively's technique significantly changes the likelihood of multiple carriers having the same phase because the carriers' phases are no longer independent of one another. Instead, multiple carriers are purposely modulated with the same bit, and thus they have the same phase. Shively suggests using groups of 4 carriers. CSCO-1011, 13:49-52. Thus, all 4 carriers in a group employing Shively's

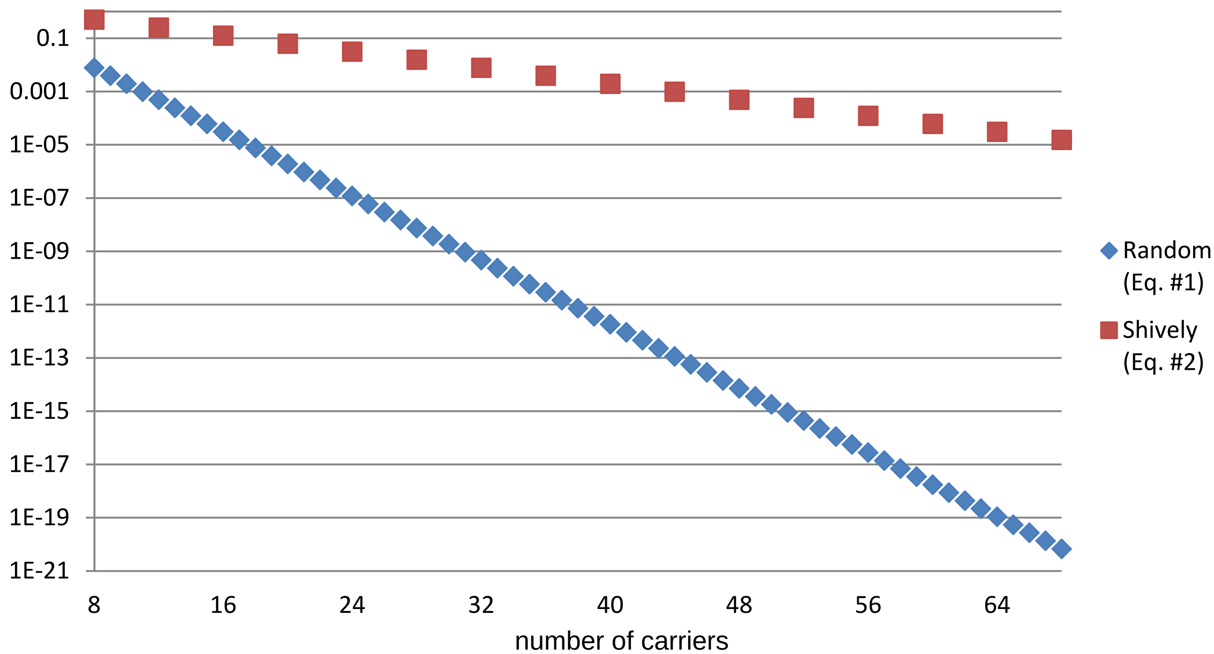
technique will have the same phase. Their likelihood of phase alignment is 100%—a stark contrast to the 12.5% chance if those 4 carriers were independent of one another. CSCO-1026, ¶24. If 8 carriers use Shively's technique (two groups of 4), the likelihood of all 8 carriers being phase-aligned is 50%; again this is in stark contrast to the 0.78% chance if those carriers had uncorrelated, random phases. *Id*. In general, the likelihood of *n* carriers all having the same phase if they are employing Shively's technique is:

$$\frac{2}{2^{\left(\frac{n}{4}\right)}} \qquad \text{Eq. 2}$$

CSCO-1026, ¶25.

3. Comparing the phase-alignment likelihoods for Shively's technique and random data

Graphing equations 1 and 2 shows that they are never very close, and they only grow farther apart as the number of subcarriers increases:



CSCO-1026, ¶26.

Thus, the probability of multiple subcarriers having their phases aligned is radically different between the random-data case and Shively's technique. The enormity of the differences is also apparent when considering how frequently a given number of carriers will be phase-aligned in a system—such as ADSL—that transmits 4000 symbols/second:

Number of carriers	**Frequency of perfect alignment for random data**	**Frequency of alignment for Shively's bit-spreading**
4	500 times per second	4000 times per second
8	31 times per second	2000 times per second
16	Once every 8 seconds	500 times per second
24	Once every 35 minutes	125 times per second
32	Once every 6 days	31 times per second
48	Once every 1100 years	2 times per second
52	One every 17,850 years	Once per second

CSCO-1026, ¶28.

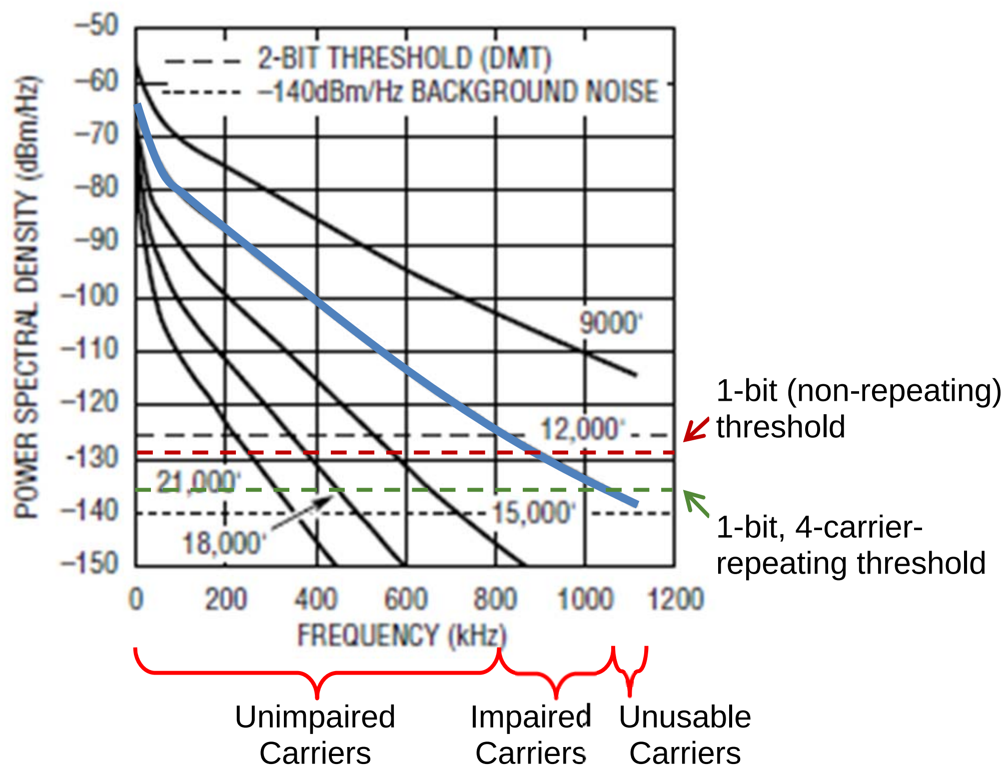
Dr. Short used an example of Shively's technique on 16 carriers. *See* TQ-2003, ¶66. A Gaussian probability distribution grossly underestimates the likelihood of phase alignment—by several orders of magnitude—and thus grossly underestimates the probability of clipping. CSCO-1026, ¶29. Dr. Short effectively assumed that all 16 carriers would be phase-aligned only once every 8 seconds. In reality Shively's technique will cause them to be phase-aligned *500 times per second*. *Id*. Because Dr. Short's numerical analysis is based entirely on an erroneous assumption, his results are unreliable. *Id*. Thus, Dr. Short's opinions and his analysis regarding Shively's PAR should not be accorded any weight.

C. A rigorous analysis of using Shively's technique shows that it significantly increases PAR and the likelihood of clipping

Because Shively's technique causes multiple subcarriers to be purposely set to the same phase, a system employing Shively's technique cannot be analyzed using a Gaussian approximation. While a POSITA would have intuitively known that Shively's technique would significantly increase PAR, quantifying the exact level of increase would have called for running a numerical simulation of the transmitter. CSCO-1026, ¶42. Such simulations were commonly created and performed by engineers working on ADSL designs in the 1990s. CSCO-1026, ¶43; *see, e.g.*, CSCO-1030, p.367; CSCO-1032, p.774; CSCO-1033, p.758; CSCO-1031, ¶¶5-6.

Consistent with what a POSITA would have done to quantify the effect of

Shively's technique on PAR, Dr. Tellado created a simulation based, in part, on TQ Delta's Exhibit 2009, Figure 6, shown below:



CSCO-2009, Fig. 6 (annotated).

To show the effect of Shively's technique on PAR, Dr. Tellado analyzed the attenuation graph of a 12,000 foot AWG 26 cable. Dr. Tellado's analysis shows that the 12,000 foot cable would have approximately 188 unimpaired (with 6 left unused), 53 impaired, and 15 unusable carriers. CSCO-1026, ¶¶37-38. Because Shively suggests grouping impaired carriers into groups of four, Dr. Tellado arranged 52 of the 53 carriers into 13 groups of 4 carriers each. CSCO-1026, ¶38.

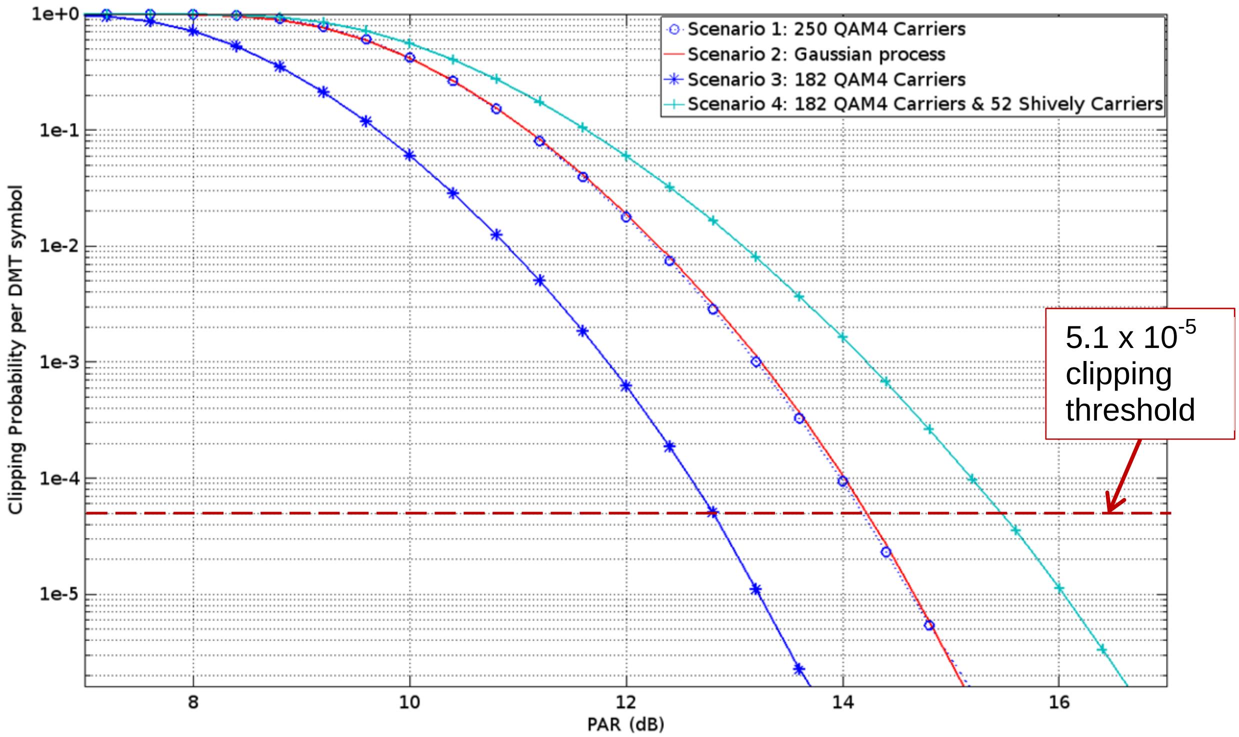
Dr. Tellado simulation uses the above analysis and includes four scenarios:

- Scenario #1: An all-carriers baseline simulates an ADSL transmitter employing QAM-4 modulation of random data on all 250 downstream carriers. The transmitter is operating on full average power. CSCO-1026, ¶47.
- Scenario #2: A Gaussian distribution with the same power as the all-carriers baseline shows that Gaussian approximation can closely estimate the power required to transmit data on all 250 carriers. *Id*.
- Scenario #3: A 12,000 foot baseline simulates an ADSL transmitter employing a QAM-4 modulation of random data on 182 out of 250 downstream carriers. Because only 182 carriers are modulated with random data, the transmitter operates on approximately 79% of full average power. *Id*.
- Scenario #4: A Shively 12,000 foot scenario simulates an ADSL transmitter employing QAM-4 modulation of random data on the 182 carriers, and using Shively's technique to transmit additional 13 bits of data spread across 52 impaired carriers (in 13 groups of 4 each). *Id*.

The graph below shows the results of the four scenarios.[4] The ANSI T1.413-

[4] Such graphs were commonly used in the prior art to evaluate transmitter designs. CSCO-1026, ¶46; CSCO-1030, p.367; CSCO-1024, p.4.

1995 standard's maximum clipping rate, when expressed in terms of DMT symbol clipping as graphed, corresponds to a DMT symbol clipping rate of approximately 5.1×10^{-5}. CSCO-1026, ¶48.



CSCO-1026, ¶¶48-49.

The impact of Shively's technique is evident in comparing Scenario #3 to Scenario #4. If only 182 carriers carry data (Scenario #3), the PAR at the clipping threshold is approximately 12.9 dB. But when Shively's technique (Scenario #4) is applied to the 52 impaired carriers (13 groups of four), the PAR increases to approximately 15.5 dB. This increase in PAR is significant, and a POSITA in the 1990s would have considered a PAR increase of 2.6 dB—representing an 82% increase in power—to be very large. CSCO-1026, ¶49.

The increase in PAR can also be appreciated by considering response of an ordinary ADSL transmitter (represented by Scenario #1 that intersects the clipping threshold at a PAR of 14.2 dB) when presented with a DMT symbol employing Shively's technique. A transmitter handling only PAR of 14.2, used in Scenario #4, would have a clipping rate of 10^{-3} and incur a clipping event approximately 4 times per second. CSCO-1026, ¶50. Thus, the ordinary ADSL transmitter would not meet the clipping requirement of ANSI T1.413-1995 when presented with a DMT symbol employing Shively's technique under the conditions of Scenario #4. CSCO-1026, ¶50.

Dr. Tellado's simulation considers only specific scenarios. Shively's technique would have an even worse impact on PAR in other scenarios that take into account additional factors, such as other line lengths and crosstalk noise. CSCO-1026, ¶51.

Thus, the correct analysis of Shively's technique confirms what a POSITA would have recognized without performing any calculations: that Shively's technique significantly increases PAR. CSCO-1026, ¶52. Because (as the parties agree) an increase in PAR is undesirable in multicarrier systems, a POSITA would have sought out to pair Shively's technique with techniques for reducing PAR, such as phase scrambling taught by Stopler. CSCO-1026, ¶54.

D. High PAR causes more problems than just clipping

TQ Delta argues that because Shively does not present "a PAR problem", there is no need to look for a solution to reduce PAR. Resp., p.50. This argument is based on TQ Delta's erroneous 18,000-foot analysis (which is invalid, as discussed above) and its attempt to limit a "PAR problem" to situations in which a "PAR-induced error[]" such as signal clipping occurs. Resp., pp.7-8. But a high PAR was known to cause multiple kinds of problems, not just clipping. Dr. Short admitted that equipment designed to handle a high PAR signal could be larger, more expensive, more power hungry, and less efficient. TQ-2003, ¶26; CSCO-1027, 45:21-46:19. He further admitted that these problems would motivate engineers to look for ways to reduce PAR. CSCO-1027, 46:23-47:2. Prior art articles confirm that engineers sought to minimize the equipment cost, power consumption, and heat generation associated with ADSL's high-PAR signals. *See* CSCO-1029, pp.70 & 176-177; CSCO-1030, p.362.

In summary, the negative implications of a high-PAR signal are not limited to signal clipping. The numerous problems associated with high PAR would have motivated a POSITA to look for ways to reduce the PAR of Shively's technique. CSCO-1026, ¶¶3, 54.

E. Stopler's diagonalization technique is optional, not required

TQ Delta argues that Shively and Stopler cannot be combined because

Stopler's "diagonalization" technique would introduce unacceptable latency. Resp., pp.51-55. TQ Delta's argument is meritless.

First, the obviousness combination does not rely on Stopler's diagonalization technique. Rather, the combination incorporates Stopler's phase scrambling technique into Shively in order to offset the PAR increase caused by Shively's technique. *See* Pet., p.14. Because the combination does not rely on diagonalization, TQ Delta's argument is simply a red herring.

Second, diagonalization is optional in Stopler, which makes statements like "regardless of whether diagonalization is being used." CSCO-1012, 10:17, 13:1-3. Thus, any incompatibility between diagonalization and Shively is irrelevant. CSCO-1026, ¶60.

Finally, TQ Delta's assertion that the slope of Stopler's diagonalization technique causes unacceptable latency is incorrect. Stopler states "[o]ther slopes may be used" and advises "taking into account trade-offs between latency and noise immunity." CSCO-1012, 8:35, 12:47-48. Thus, Stopler's diagonalization technique could use a slope that would not cause unacceptable latency. CSCO-1026, ¶61.

F. Ground #2: Combining Bremer with Shively and Stopler would have been obvious

Regarding claims 6 and 20,[5] TQ Delta asserts that Cisco provided an insufficient rationale for combining Bremer's teaching of a complementary pseudorandom number generator with Shively and Stopler. However, Cisco provided a detailed explanation of the rationale, supported by the opinion of Dr. Tellado. *See* Pet. pp.42-47 (*citing* CSCO-1009, pp.75-81). Notably, Dr. Short did not offer any testimony in support of TQ Delta's position.

Indeed, Dr. Short largely agrees with Cisco's position that a POSITA would have recognized the need for a second pseudorandom number generator (taught Bremer) in a receiver communicating with Shively's transmitter. In his book chapter, Dr. Short explained that when scrambling is performed in a transmitter based on a pseudorandom sequence (as in Stopler), the receiver needs to use the same pseudorandom sequence to descramble the data. CSCO-1022, p.93. Dr. Short also wrote that "Of course, the receiver must use the same seed value as the transmitter for the descrambling to work properly." CSCO-1022, p.94. Dr. Short further confirmed that these concepts would have been known to a POSITA. CSCO-1026, 89:11-90:5. Thus, Dr. Short's testimony supports Dr. Tellado's opinion that it would have been obvious to a POSITA "that the second transceiver

[5] The Patent Owner Response (p.59) mistakenly refers to claims 6 and 15.

of Shively/Stopler (which receives data from the first transceiver) should include a second pseudo-random number generator, as taught by Bremer." CSCO-1009, p.78. Dr. Short also supports Dr. Tellado's opinion that "it would have been obvious to a POSITA to incorporate the use of the same seed value at the remote receiver." CSCO-1009, p.95.

Finally, TQ Delta argues that Bremer's teaching is inapplicable because Bremer is a single-carrier system, while Shively and Stopler are multicarrier systems. Resp., pp.60. But as Dr. Tellado explained, Bremer's concept can be "applied on a carrier-by-carrier basis" (CSCO-1009, p.81), that is, treating each of Shively/Stopler's multiple carriers (QAM symbols) independently. This application of Bremer's teachings to a multicarrier system is consistent with Stopler's description of applying phase rotations (determined via a pseudorandom number generator) to individual QAM symbols. CSCO-1012, 12:31-45.

VI. Conclusion

None of the TQ Delta's arguments withstand scrutiny. For the reasons above and in Cisco's Petition, the Board should find all claims unpatentable.

Respectfully submitted,

Date: June 8, 2017

/David L. McCombs
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VII. Certificate of Word Count

Pursuant to 37 C.F.R. § 42.24, the undersigned attorney for the Petitioner, Cisco Systems, Inc. ("Cisco"), declares that the argument section of this Petition (Sections I-VI) has a total of 5599 words, according to the word count tool in Microsoft Word™.

/David L. McCombs/
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CERTIFICATE OF SERVICE

The undersigned certifies service under 37 C.F.R. §§ 42.6(e) by electronic mail a true and correct copy of *PETITIONER'S REPLY AND EXHIBITS 1021-1034* on June 8, 2017, upon counsel for the Patent Owner via the listed email below:

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Paper 24
Entered: June 22, 2017

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CISCO SYSTEMS, INC., DISH NETWORK, LLC,
COMCAST CABLE COMMUNICATIONS, LLC,
COX COMMUNICATIONS, INC.,
TIME WARNER CABLE ENTERPRISES LLC,
VERIZON SERVICES CORP., and ARRIS GROUP, INC.,
Petitioner,

v.

TQ DELTA, LLC,
Patent Owner.

Cases IPR2016-01006 (Patent 7,835,430 B2)[1]
IPR2016-01008 (Patent 8,238,412 B2)
IPR2016-01020 (Patent 9,014,243 B2)
IPR2016-01021 (Patent 8,718,158 B2)

[1] DISH Network, L.L.C., Comcast Cable Communications, L.L.C., Cox Communications, Inc., Time Warner Cable Enterprises L.L.C., Verizon Services Corp., and ARRIS Group, Inc. have been joined in these proceedings. *See,* IPR2017-00251, IPR2017-00253, IPR2017-00254, IPR2017-00255, IPR2017-00417, IPR2017-00418, IPR2017-00419, and IPR2017-00420. This Order addresses the same issues in the above listed proceedings. Therefore, we issue one Order to be filed in all of the above listed proceedings. The parties, however, are not authorized to use this style of filing in subsequent papers.

Before SALLY C. MEDLEY, KALYAN K. DESHPANDE, and TREVOR M. JEFFERSON, *Administrative Patent Judges*.

MEDLEY, *Administrative Patent Judge*.

ORDER
Conduct of the Proceeding
37 C.F.R. § 42.5

On June 21, 2017, a conference call was held involving counsel for the respective parties and Judges Medley, Deshpande, and Jefferson. The purpose of the conference call was for Patent Owner to seek authorization to file a motion to strike Petitioner's Reply and/or to file a sur-reply to Petitioner's Reply in each of the above listed proceedings. Patent Owner opposed.

During the conference call, we explained that Patent Owner is not authorized to file motions to strike or sur-replies. We did authorize, however, Patent Owner to file a paper, limited to two pages, which provides an itemized listing, by page and line number, of what statements and evidence in the Petitioner's Reply are deemed by Patent Owner to be beyond the proper scope of a reply. No argument is to be included in the contents of the submission. We also authorized Petitioner to file a responsive paper, limited to two pages, which provides an item-by-item response to the items listed in Patent Owner's submission. Each item in Petitioner's responsive paper would identify that part of Patent Owner's Response, by page and line number, to which the corresponding item complained of by the Patent Owner is provided as a response, if indeed that is the case. No argument is to be listed in the contents of the submission.

Accordingly, it is

ORDERED that Patent Owner's submission in each of the above listed proceedings is due on June 27, 2017; and

FURTHER ORDERED that Petitioner's submission in each of the above listed proceedings is due on July 3, 2017; and

FURTHER ORDERED that the party responsible for obtaining the court reporter shall file a copy of the transcript of the conference call as an exhibit by June 27, 2017.

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IPR2016-01008 (Patent 8,238,412 B2)
IPR2016-01020 (Patent 9,014,243 B2)
IPR2016-0102 (Patent 8,718,158 B2)

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UNITED STATES PATENT AND TRADEMARK OFFICE

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TIME WARNER CABLE ENTERPRISES LLC,
VERIZON SERVICES CORP., and ARRIS GROUP, INC.,
Petitioner,

v.

TQ DELTA, LLC,
Patent Owner.

Case IPR2016-01021[1]
Patent 8,718,158 B2

[1] DISH Network, L.L.C., who filed a Petition in IPR2017-00255, and Comcast Cable Communications, L.L.C., Cox Communications, Inc., Time Warner Cable Enterprises L.L.C., Verizon Services Corp., and ARRIS Group, Inc., who filed a Petition in IPR2017-00417, have been joined in this proceeding.

Patent Owner's expert, Dr. Short, are based on the long loops with high attenuation and noise to which Shively's teachings are directed.

<u>Observation #3</u>

In Ex. 2013, at 46:10–47:20, Dr. Tellado testified:

Q. Did you run a simulation --

A. Yes.

Q. -- using an 18,000-foot loop with the attenuation characteristics shown in Figure 6 on page 18 of your declaration?

A. So in this AWG26 loop of 18,000 feet, I did a quick estimate.

Q. But you didn't run a full simulation on it?

A. Not a full simulation.

***

Q. What did you determine from your quick estimate?

A. That Dr. Short's approximation of a Gaussian approximation was poor. It was worse than -- than Dr. Short said.

Q. How much worse?

A. I don't recall. It was significantly worse.

Q. You don't recall. Did you run a simulation?

A. I said I ran a quick estimate to see if the Gaussian approximation was good, and it was not.

Q. How did you do that quick estimation?

A. Using similar techniques to the ones that I provided.

Q. Where is that simulation?

> A. So when I started working the declaration, I just did a quick estimate to see if the Gaussian approximation was correct, and I determined it was not.
>
> Q. Did you use MATLAB for that?
>
> A. Yes.
>
> Q. Where are the results of that MATLAB?
>
> A. I don't have them.

That testimony is relevant to the credibility of, sufficiency of, and factual basis for Dr. Tellado's statement, in Ex. CSCO-1026 at ¶ 29 (p. 17), that "Dr. Short's analysis is flawed …." The testimony is relevant because (1) it shows that, in evaluating Dr. Short's analysis, Dr. Tellado did not run a "full simulation," he does not "recall" the results, and he no longer has the results, and (2) that simulation would show whether Dr. Short's analysis is flawed.

Observation #4

In Ex. 2013, at 50:6–56:17, Dr. Tellado testified:

> Q. Are you suggesting that Dr. Short's -- if you had run a full simulation on Dr. Short's 18,000-foot loop, assuming the 88 usable carriers and 16 Shively carriers and the remainder unusable, are you telling me that that would be worse than your Scenario 1 here?
>
> A. I didn't say that. I just said it was diverging relative to a Gaussian process.
>
> ***
>
> Q. If we were to run a Gaussian on the 104 carriers that you ran this quick simulation on, where would that line show up in graph 2 on your -- page 30 of your declaration?

2003 at ¶ 63 (p. 32), that "[w]hile Shively's 'spreading' idea will cause a small uptick in clipping probability, any increase is negated many times over by the enormous reduction in clipping achieved by reducing signal power by more than half. Based on worst-case assumptions regarding Shively's spreading idea, the clipping probability for both normal and power-boost modes is virtually zero." The testimony is relevant because it shows that Dr. Tellado does not know whether Dr. Short's conclusion is flawed.

Observation #5

In Ex. 2013, at 58:10–60:24, Dr. Tellado testified:

> Q. So Dr. Tellado, did you save, in any form, your MATLAB simulation script for the 18,000-foot loop scenario?
>
> MR. McDOLE: Objection; asked and answered.
>
> THE WITNESS: I don't recall.
>
> ***
>
> Q. Did you share with anyone, including your lawyers, a copy of your MATLAB simulation script for 88 usable carriers and 16 Shively carriers?
>
> A. I don't recall.
>
> ***
>
> Q. Did you save, in any form, the output of your MATLAB simulation for the 88 random carriers and 16 Shively carriers?
>
> A. I don't recall.
>
> Q. Do you currently have in your possession, in any form, the output of your MATLAB simulation for the 88 usable carriers and 16 Shively carriers?

A. I don't recall.

That testimony is relevant to the credibility of, sufficiency of, and factual basis for Dr. Tellado’s statement, in Ex. CSCO-1026 at ¶ 29 (p. 17), that “Dr. Short’s analysis is flawed ….” The testimony is relevant because it shows that Dr. Tellado used a MATLAB simulation to evaluate the 18,000 foot loop scenario that Dr. Short relied on, but Dr. Tellado “does not recall” whether any record of that simulation still exists, and that simulation would show whether Dr. Short’s analysis is flawed.

<u>Observation #6</u>

In Ex. 2013, at 114:12-16 and 116:18-20, Dr. Tellado testified:

Q. Do you know intuitively whether 88 random carriers and 16 Shively carriers would have a lower probability of clipping than Scenario 2?

MR. McDOLE: Objection; form.

THE WITNESS: No, I’m not going to guess.

***

Q. Do you know intuitively whether Scenario 5 presents a lower chance of clipping than Scenario 2?

A. I don’t want to guess.

That testimony is relevant to (1) the scenarios shown on the graph in Ex. 2011 and (2) the credibility of Dr. Tellado’s statement, in Ex. CSCO-1026 at ¶ 52 (p. 32), about “what a POSITA would have intuitively recognized without performing mathematical calculations.” The testimony is relevant because Ex.

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UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

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COX COMMUNICATIONS, INC.,
TIME WARNER CABLE ENTERPRISES LLC,
VERIZON SERVICES CORP., and ARRIS GROUP, INC.,
Petitioner,

v.

TQ DELTA, LLC
Patent Owner

Case No. IPR2016-01021[1]
Patent No. 8,718,158

PATENT OWNER'S MOTION TO EXCLUDE EXHIBITS 1022, 1023, 1024, 1025, and 1028, PORTIONS OF THE TELLADO TESTIMONY (EX. 2013), AND PORTIONS OF THE 2nd TELLADO DECLARATION (EX. 1026) PURSUANT TO 37 C.F.R. § 42.64(c)

[1] DISH Network, L.L.C., who filed a Petition in IPR2017-00255, and Comcast Cable Communications, L.L.C., Cox Communications, Inc., Time Warner Cable Enterprises L.L.C., Verizon Services Corp., and ARRIS Group, Inc., who filed a Petition in IPR2017-00417, have been joined in this proceeding.

I. INTRODUCTION

Patent Owner TQ Delta, LLC submits the following motion to exclude. The exhibits in question should be excluded for Petitioner's failure to cite documents that constitute prior art, its untimely introduction of exhibits on Reply that are irrelevant to the substantive issues and not cited in the Reply, rendering them irrelevant, and its expert's failure to retain copies of testing he performed on which he relies.

II. EXHIBITS 1022, 1023, 1024, 1025, AND 1028, PORTIONS OF THE TELLADO TESTIMONY (EX. 2013) AND PORTIONS OF THE SECOND TELLADO DECLARATION (EX. 1026) SHOULD BE EXCLUDED

A. EXHIBIT 1022 SHOULD BE EXCLUDED UNDER AT LEAST FED. R. EVID. 402

Exhibit 1022 is a chapter and some additional pages from a book titled *WiMedia UWB.* Patent Owner timely objected to Exhibit 1025. *See* Paper 25 at 1.

Exhibit 1022 was not included with the Petition and it is not cited or explained in the Reply. It is also not cited in the Second Tellado Declaration (submitted with the Petitioner Reply). Exhibit 1022 should be excluded for this reason alone as irrelevant and untimely under Fed. R. Evid. 402, Fed. R. Evid. 403, 37 C.F.R. § 42.23, and/or 37 C.F.R. § 42.61.

Moreover, Exhibit 1022 should be excluded as irrelevant because it is not prior art and therefore irrelevant to the knowledge of one of ordinary skill in the art as of 1999. Both the book itself and the chapter in question (Ch. 3) bear copyright dates of 2008. *See* Ex. 1022 at 3, 11. Patent Owner timely objected to Exhibit 1025. *See* Paper 25 at 2. There is no evidence that the book or the chapter cited were publicly-available or otherwise constituted prior art as of 1999, the filing date of the ’158 patent. *See* Ex. 1001 at cover. In other words, Exhibit 1022 is nine years too late. Exhibit 1022 is irrelevant to show or evidence the knowledge of one of ordinary skill as of the date the invention was made.

The relevant time-frame for patentability is the time of the invention, and no later than the effective filing date. *See* *Synthon IP, Inc. v. Pfizer, Inc.*, C.A. No. 1:05cv1267, 2007 U.S. Dist. LEXIS 26115, at *15-17 (E.D. Va. Apr. 6, 2007) (“[T]he obviousness inquiry asks whether the subject matter ‘would have been obvious [to one of ordinary skill in the art] *at the time the invention was made*.’”), quoting *Alza Corp. v. Mylan Labs., Inc.*, 464 F.3d 1286, 1289 (Fed. Cir. 2006) (emphasis added in *Synthon*); *Walt Disney Prods. v. Fred A. Niles Communs. Ctr., Inc.*, 369 F.2d 230, 234 (7th Cir. 1966) (“The difference between the subject matter sought to be patented and the prior art must be such that the subject matter as a whole would have been obvious to a person having ordinary skill in the art to

which said subject matter pertains, as of the date of the invention.”; explaining that the use of knowledge from a later date constituted impermissible hindsight).

Because Exhibit 1022 was nine years too late, it is irrelevant under Fed. R. Evid. 402, and should be excluded.[2]

B. EXHIBIT 1025 SHOULD BE EXCLUDED AS IRRELEVANT UNDER AT LEAST FED. R. EVID. 402

Exhibit 1025 is a thesis from Petitioner’s Expert. It should be excluded for multiple reasons. Patent Owner timely objected to Exhibit 1025. *See* Paper 25 at 2.

Petitioner submitted Exhibit 1025 (Tellado thesis) for the first time on Reply. Like Exhibit 1022, the thesis was not cited in either the Petition or the Reply. Exhibit 1025 should be excluded for this reason alone as irrelevant and untimely under F.R.E. 402, F.R.E 403, 37 C.F.R. § 42.23, and/or 37 C.F.R. § 42.61.

Moreover, Exhibit 1025 should be excluded as irrelevant because it is not prior art and therefore irrelevant to the knowledge of one of ordinary skill in the art as of 1999. The only expert testimony offered by Petitioner in this case is offered to show the viewpoint of a person of ordinary skill in the art as of the filing date of

[2] Exhibit 1022 should also be excluded because it is not cited in either the Reply or the Second Tellado Declaration.

November 9, 1999. *See* Ex. 1009 ¶ 7. But, like Exhibit 1022, there is no evidence that the Tellado thesis was publicly accessible as of this filing date. The Tellado thesis itself lists two dates, without explanation—(1) a copyright date of 2000 (Ex. 1025 at 2); and (2) the statement "September 1999" under the author's name. *Id.* at 1. After Patent Owner's objection to Ex. 1025, Petitioner submitted supplemental evidence to allege only that the thesis was "catalogued by the Stanford University Libraries on May 9, 2000 (field 916) and was publicly available from the Stanford University Libraries since this date." Ex. 1035 ¶ 2, at 2.

The proponent of the publication, here Petitioner, bears the burden of producing sufficient proof of dissemination or sufficient proof that the publication was otherwise available and accessible. *See SRI Int'l, Inc. v. Internet Sec. Sys., Inc.*, 511 F.3d 1186, 1194 (Fed. Cir. 2008); *see also Carella v. Starlight Archery & Pro Line Co.*, 804 F.2d 135, 139 (Fed. Cir. 1986) ("[O]ne who wishes to characterize the information, in whatever form it may be, as a 'printed publication' should produce sufficient proof of its dissemination or that it has otherwise been available and accessible to persons concerned with the art to which the document relates . . . .").

To be relevant, a publication must have been publicly accessible as of the effective filing date. In this case, Petitioner has admitted that the relevant date, and indeed the only date on which its expert offers his opinions regarding the

knowledge of a person of ordinary skill is November 9, 1999. *See* Ex. 1009 ¶ 7. The supplemental evidence submitted by Petitioner shows, at best, a date of public accessibility ("catalog[ing]") of May 9, 2000, which falls **after** date of knowledge of a person of ordinary skill (November 9, 1999) proffered by Petitioner's expert (*see* Ex. 1009 ¶ 7). That date, not surprisingly, matches the earliest claimed filing date for the '158 patent. *See* Ex. 1001 at cover; Ex. 1008. Therefore, the Tellado thesis (Ex. 1025) is too late in time and is irrelevant to the testimony of Tellado, and irrelevant to this review under Fed. R. Evid. 402.

C. ALL OR PORTIONS OF PARAGRAPHS 16, 29, 42 (INCLUDING HEADER), 43, AND 52 OF THE SECOND TELLADO DECLARATION (EX. 1026) AND PAGES 46:19-47:16, 49:1-50:13, 51:5-56:23, 57:6-12, AND 61:19-23 OF THE TELLADO TRANSCRIPT (EX. 2013) SHOULD BE EXCLUDED

During cross-examination, Petitioners' expert (Dr. Tellado) testified that he relied on at least two "MatLab" computer simulations to support his opinions, but materials relating to only one simulation were provided to Patent Owner. The materials related to the second simulation were apparently written over, discarded, and/or withheld from Patent Owner. *See* Ex. 2013 at 47:9-48:6, 57:6-17, 58:10-14, 59:6-12, 60:3-8, 60:9-20. Patent Owner timely objected to the failure to disclose or retain evidence and the possible discarding of evidence. *See* 6/22/17 A. Karp e-

mail to counsel; 6/22/17 A. Karp e-mail to Board; Ex. 2013 at 57:25-58:2, 62:13-63:4.

In addition to the testing of the 12,000 foot loop that Dr. Tellado performed and disclosed in connection with his second declaration, Dr. Tellado also performed an undisclosed simulation using a MatLab script for an "AWG26 loop of 18,000 feet." Ex. 2013 at 46:10-18. But, Dr. Tellado testified on cross-examination that the MatLab script and simulation results for an 18,000 foot loop formed the basis of his opinion that Dr. Short's (Patent Owner's expert) Gaussian approximation was "poor." *See, e.g.*, Ex. 2013 at 46:19-47:8, 51:5-20, 52:25-53:12. When asked about whether he has or had an electronic or hard copy of the MatLab script or simulation results, whether he communicated the same to anyone else, or whether he discarded or deleted the same, Dr. Tellado could only say that did not recall. *See, e.g.*, *id.* at 47:9-48:6, 57:6-17, 58:10-14, 59:6-12, 60:3-8, 60:9-20.

Without providing Patent Owner with access to the MatLab simulation result, Dr. Tellado has not disclosed the facts and data underlying his opinion, in violation of 37 C.F.R. § 42.65(b). Under Rule 65(b), when Petitioner's expert relied on a technical test or data from it, he was required to "provide an affidavit explaining" the test and its underlying data. *See* 37 C.F.R. § 42.65(b) (setting forth the requirements of the affidavit); *3D-Matrix, Ltd., v. Menicon Co., Ltd.*, IPR2014-

00398, Paper 11, August 1, 2014. Moreover, it remains impossible to cross-examine Dr. Tellado regarding his opinions regarding simulations and his criticisms of Dr. Short, as reflected in at least (1) Exhibit 1026, Second Tellado Declaration, ¶ 16 (last 2 sentences), ¶ 29, ¶ 42 (including preceding header), ¶ 43 (first sentence), ¶ 52, and (2) Exhibit 2013, Tellado transcript at 46:19-47:16, 49:1-50:13, 51:5-56:23, 57:6-12, and 61:19-23. *See Altaire Pharma., Inc. v. Paragon Biotek, Inc.*, PGR2015-00011, Paper 122, November 14, 2016 ("Without the necessary information prescribed in § 42.65(b), we cannot determine whether the evidence Petitioner relies on is credible.").

Moreover, the unavailable MatLab simulation information was required to be disclosed as routine discovery at least because (1) it was relied on or cited by Dr. Tellado during his testimony under 37 C.F.R. §§ 41.51(b)(1)(i); *see Lumentum Holdings, Inc. v. Capella Photonics, Inc.*, IPR2015-00731, Paper 32, February 5, 2016 (information relied on was required to be disclosed regardless of whether it was actually called an exhibit in a paper); *MaxLinear, Inc., v. Cresta Tech. Corp.*, IPR2015-00594, Paper 35, January 27, 2016 (testimony referencing an exhibit, although not formally; and (2) it is inconsistent, at least, with Petitioners' (and Petitioners' expert's) positions regarding the accuracy of Dr. Short's analysis. 37 C.F.R. §§ 42.51(b)(1)(i), (b)(1)(iii); *see also MaxLinear*, IPR2015-00594, Paper 35. Therefore, this information should already have been produced.

As a result of the improper withholding, the following paragraphs of the Second Tellado Declaration (Ex. 1026) should be excluded under Fed. R. Evid. 702 as being based on insufficient facts or data: ¶ 16 (last 2 sentences), ¶ 29, ¶ 42 (including preceding header), ¶ 43 (first sentence), and ¶ 52. For the same reasons, the following pages of the Tellado transcript (Ex. 2013) should be excluded under Fed. R. Evid. 702: 46:19-47:16, 49:1-50:13, 51:5-56:23, 57:6-12, and 61:19-23.

As a result of Dr. Tellado's refusal to disclose the underlying facts and data on cross-examination, the same portions of the Second Tellado Declaration (Ex. 1026) and the Tellado transcript (Ex. 2013) should also be excluded under Fed. R. Evid. 705.

For at least these reasons, and due to Dr. Tellado's withholding of the simulation data, the above-referenced portions of the Second Tellado Declaration (Ex. 1026) and Tellado transcript (Ex. 2013) should be excluded under Fed. R. Evid. 702, 705, 37 C.F.R. §§ 41.51(b)(1)(i) & 41.51(b)(1)(iii), and 37 C.F.R. § 42.65(b).

D. EXHIBITS 1023, 1024, AND 1028, AND PORTIONS OF DR. TELLADO'S REDIRECT ADDRESSING THE SAME (EX. 2013) SHOULD BE EXCLUDED UNDER F.R.E. 402, F.R.E 403, 37 C.F.R. § 42.23, AND/OR 37 C.F.R. § 42.61

Exhibits 1023, 1024, and 1028, each of which was cited in the Reply for the first time, should be excluded under F.R.E. 402, F.R.E 403, 37 C.F.R. § 42.23,

and/or 37 C.F.R. § 42.61. Patent Owner timely objected to these exhibits. *See* Paper 25 at 1-2. Similarly, the portions of Dr. Tellado's redirect regarding the same (Ex. 2013 at 146:20-149:7 (Ex. 1023), 149:8-152:25 (Ex. 1024)) should also be excluded under F.R.E. 402, F.R.E 403, 37 C.F.R. § 42.23, and/or 37 C.F.R. § 42.61. Patent Owner also timely objected to this redirect testimony. *See* Ex. 2013 at 146:20-149:7, 149:8-152:25

These exhibits purportedly attempt to fill in a major shortcoming in the evidentiary record—namely, there is no evidence in the Petition (besides an unsupported, conclusory allegation by Petitioners' expert) that a person having ordinary skill in the art would have recognized that randomizing the phases of subcarriers in a multicarrier signal would result in a lower peak-to-average power ratio ("PAR") in Shively's system. Both the Petition and Petitioners' expert's first declaration baselessly state: "A POSITA would have recognized that by randomizing the phase of each subcarrier, Stopler provides a technique that allows two subcarriers in Shively's system to transmit the same [one or more] bits, but without those two subcarriers having the same phase." Petition at p. 14; Ex. 1009 (Dr. Tellado's First Declaration) at ¶ 67. No supporting evidence was provided.

Now, when Patent Owner has no chance to respond, Petitioners seek to remedy this deficiency in the Petition (and first expert declaration) through attorney argument regarding these exhibits. Exhibit 1023, Petitioners allege,

discloses "random phasor transformation" (Paper 20 at 13)—although they never explain how such a "phasor" transformation equates to randomizing phases on each subcarrier to reduce PAR. With respect to Exhibit 1024, Petitioners purport that it discloses "phase rotated signal parts," Paper 20 at 13, again with no further explanation as to how this shows phase scrambling. And regarding Exhibit 1028, Petitioners merely claim it demonstrates having a "phase rotation applied to each [DMT] tone." Paper 20 at 13. Again, no explanation is provided as to how this equates to phase scrambling to lower PAR.

Thus, Exhibits 1023, 1024, and 1028 are too late and not relevant to the timely opinions and art actually raised in this review, and thus inadmissible under F.R.E. 402, 37 C.F.R. § 42.23, and/or 37 C.F.R. § 42.61. Petitioners should not be allowed to supplant the record by filling in the gaps left by their Petition and supporting declaration. Moreover, because Patent Owner has no opportunity to respond to the new exhibits at this late stage, the danger of unfair prejudice substantially outweighs any minimal probative value they may have, rendering them inadmissible under Fed. R. 403.

Recognizing the shortcoming in its citations, Petitioner took up these topics on deposition redirect of its own expert also, in an untimely attempt to fill in the gaps. *See* Ex. 2013 at 146:20-149:7 (Ex. 1023), 149:8-152:25 (Ex. 1024). Having failed to address these exhibits in its Petition, first Tellado Declaration, and Second

Tellado Declaration, these exhibits are too late and not relevant to the timely opinions and art actually raised in this review, and thus inadmissible for the same reasons under Fed. R. Evid. 402, 403, 37 C.F.R. § 42.23, and/or 37 C.F.R. § 42.61.

III. CONCLUSION

For all the foregoing reasons, TQ Delta respectfully requests that the Board exclude Exhibits:

- Exhibit 1022, *WiMedia UWB* (including Chapter 3);
- Exhibit 1025, the Tellado thesis;
- Exhibit 1026, the Second Tellado Declaration, ¶ 16 (last 2 sentences), ¶ 29, ¶ 42, ¶ 43 (first sentence), ¶ 52;
- Exhibit 2013, the Tellado Transcript, at 46:19-47:16, 49:1-50:13, 51:5-56:23, 57:6-12, and 61:19-23;
- Exhibit 1023, 1024, and 1028, newly-cited art; and
- Exhibit 2013, The Tellado Transcript, at 146:20-149:7 and 149:8-152:25.

Dated: June 30, 2017

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CUSTOMER NUMBER: 23446

CERTIFICATE OF SERVICE

I hereby certify that the Patent Owner Motion to Exclude in connection with *Inter Partes* Review Case IPR2016-01021 was served on this 30th day of June, 2017 by electronic mail to the following:

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UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CISCO SYSTEMS, INC., DISH NETWORK, LLC,
COMCAST CABLE COMMUNICATIONS, LLC,
COX COMMUNICATIONS, INC.,
TIME WARNER CABLE ENTERPRISES LLC,
VERIZON SERVICES CORP., and ARRIS GROUP, INC.,
Petitioner,
v.
TQ DELTA, LLC
Patent Owner

Case No. IPR2016-01020 (Patent No. 9,014,243)[1]
Case No. IPR2016-01021 (Patent No. 8,718,158)[2]

PATENT OWNER'S MOTION FOR DISCOVERY FILED UNDER 37 C.F.R. § 42.51(b)

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[1] DISH Network, L.L.C., who filed a Petition in IPR2017-00254, and Comcast Cable Communications, L.L.C., Cox Communications, Inc., Time Warner Cable Enterprises L.L.C., Verizon Services Corp., and ARRIS Group, Inc., who filed a Petition in IPR2017-00418, have been joined in this proceeding.

[2] DISH Network, L.L.C., who filed a Petition in IPR2017-00255, and Comcast Cable Communications, L.L.C., Cox Communications, Inc., Time Warner Cable Enterprises L.L.C., Verizon Services Corp., and ARRIS Group, Inc., who filed a Petition in IPR2017-00417, have been joined in this proceeding.

Patent Owner requests that the Board issue an order compelling Petitioner to serve, within two business days, the documents identified in Ex. 2015.

The Patent Owner Response, and supporting expert declaration of Dr. Short, demonstrated that a POSITA would not recognize Shively's transmitter as suffering from a problematic increase in peak-to-average power ratio ("PAR") and, thus, there is no basis for Petitioner's asserted motivation to combine Shively with Stopler. Petitioner's Reply, based on the testimony of Dr. Tellado, contends that Dr. Short's analysis of Shively is wrong. Dr. Tellado's testimony relied on two Matlab simulations—an "18,000 foot" simulation (*see* Ex. 2013 at 45:23–47:18)[3] and a "12,000 foot" simulation (*see* Ex. 1026 at ¶¶ 43-52). Petitioner only served Patent Owner records for the 12,000 foot simulation. Undoubtedly, Petitioner withheld the 18,000 foot simulation because it would support Dr. Short and be inconsistent with Petitioner's obviousness challenge.

Because Petitioner's expert relied on the 18,000 foot simulation, and it is inconsistent with Petitioner's assertions, records of the 18,000 foot simulation are discoverable under 37 C.F.R. § 42.51(b)(1) or 37 C.F.R. § 42.51(b)(2).

I. BACKGROUND OF THE CASE

The Board instituted this IPR in reliance on Petitioner's assertions that

[3] For this jointly captioned brief, all citations are to IPR2016-01020.

"Shively's transmitter would suffer from an increased peak-to-average power ratio[,]" and "that a [POSITA] 'would have sought out an approach to reduce the [(peak-to-average power ratio)] PAR of Shively's transmitter' and 'Stopler provides a solution for reducing the PAR of a multicarrier transmitter.'" Paper 7 at 11–12. The purported problem of increased PAR is the sole motivation proffered by Petitioner to combine Shively and Stopler. Paper 2 at 15 ("Combining Stopler's phase scrambler into Shively's transmitter would have been a relatively simple and obvious solution to reduce Shively's PAR.").

Patent Owner Response: Patent Owner, relying on Dr. Short's declaration, rebutted Petitioner's bald conclusion that "the PAR of Shively's transmitter" presented a problem that a POSITA would seek to remedy. Paper 12 at 48. Dr. Short explained "why any arguable 'increase' in PAR due to Shively's 'spreading' scheme is trivial in view of Shively's drastic reduction in transmission signal power (which virtually eliminates clipping)." *Id*. (citing Ex. 2003 at ¶¶ 61–67).

Dr. Short analyzed an 18,000 foot loop because Shively is expressly directed to "long loop systems, where the length of cable … is at least 18,000 feet." Ex. 2003 at ¶ 44 (citing Shively at 9:63–10:2 and 11:11–12)). Dr. Short explained that multicarrier systems are designed to accommodate significant PAR, and increased PAR is problematic only if it causes clipping at rate greater than allowed by the

relevant communication standard. Ex. 2003 at ¶¶ 23–32. He explained that per Shively's teachings "more than half of the carrier cannot be used at all." *Id.* at ¶ 58. Dr. Short continued, "While Shively's 'spreading' idea will cause a small uptick in clipping probability, any increase is negated many times over by the enormous reduction in clipping achieved by reducing signal power by more than half" (*id.* at ¶ 63) and concluded that Shively does not cause a PAR problem . *Id.* at ¶¶ 62–67.

Petitioner's Reply: Petitioner defended its flawed and conclusory obviousness rationale by disparaging Dr. Short's analysis of an 18,000 foot loop and claiming that Dr. Short's "results are unreliable." Paper 17 at 31. Petitioner and Dr. Tellado assert that quantifying the increase in PAR "would have called for running numerical simulations." Paper 17 at 34; Ex. 1026 at ¶ 43. "In order to quantify the increase in PAR, [Dr. Tellado] designed and wrote a simulation of an ADSL transmitter that calculates the clipping probability of a DMT symbol for different values of PAR under different simulation conditions." Ex. 1026 at ¶ 43. Nevertheless, despite that (1) Shively is directed to "long loop systems … of the order 18,000 feet or more," (2) Dr. Short analyzed an 18,000 foot loop, and (3) Dr. Tellado and Petitioner assert that quantifying any PAR problem with Shively called for a simulation, Petitioner only served Patent Owner with code for a 12,000 foot simulation (Ex. 1034) and the results (Graph 2 of Ex. 1026 at ¶ 48).

Cross-examination: Dr. Tellado testified that he performed a simulation on an 18,000 foot loop. Ex. 2013 at 45:23–47:18. Further, when asked what he had determined from it, Dr. Tellado answered: "That Dr. Short's approximation of a Gaussian approximation was poor. It was worse than – than Dr. Short said." *Id.* at 46:24–47:1.

Existence of records of the 18,000 foot simulation: Petitioner does not deny that it has or at least *had* the 18,000 foot simulation code and results. When asked by the Panel whether "there [is] a simulation or some information Dr. Tellado performed that has not been provided to Patent Owner," Cisco's counsel provided only a self-serving non-answer: "[W]e don't believe that there is anything Dr. Tellado has relied on for his analysis that's not been provided to the Patent Owner." Ex. 2016 at 20:4–13. Dr. Tellado was also evasive about the 18,000 foot simulation code and results, saying he did not "recall" whether he saved them or shared them with anyone (Ex. 2013 at 57:1–25) and refusing to state whether the results supported Dr. Short (*id.* at 53:25–56:21, 64:11–18, and 111:14–114:16).

II. THE 18,000 FOOT SIMULATION IS "ROUTINE DISCOVERY"

A. Petitioner and Its Expert Relied on the 18,000 Foot Simulation

Dr. Tellado testified that he ran an 18,000 foot simulation. Ex. 2013 at 45:23–47:11. Importantly, Petitioner and Dr. Tellado asserted that a POSITA would have to do a simulation to quantify whether a PAR problem is created on a

given loop. Paper 17 at 34; Ex. 1026 at ¶ 43. Thus, pursuant to Petitioner and Dr. Tellado's own assertions, they necessarily relied on the 18,000 foot simulation to disparage Dr. Short's opinions. *Id.* at 46:22–47:8; *see also* Ex. 1026 at ¶ 16. Any contention by Petitioner that Dr. Tellado's second declaration does not refer to the 18,000 foot simulation—and that therefore it is not an exhibit cited in a paper or in testimony—is irrelevant. By relying upon the 18,000 foot simulation to disparage Dr. Short's opinion, Petitioner "utilized information [resulting from the simulation] as an exhibit, regardless of whether Petitioner called it an exhibit." *Lumentum Holdings, Inc. et al. v. Capella Photonics, Inc.*, IPR2015-00731, Paper 32 at 3 (PTAB Feb. 5, 2016). Accordingly, the Board should order Petitioner to produce all records of its 18,000 foot simulation under 37 CFR § 42.51(b)(1)(i).

B. 18,000 Ft. Simulation Is Inconsistent With Petitioner's Assertions

In the Reply, Petitioner asserts that Dr. Tellado created and ran a simulation to determine whether "Shively's transmitter would suffer from an increased peak-to-average power ratio" as alleged in the Petition. Paper 17 at 31–34; Paper 2 at 14. Notably, this simulation was created only after Patent Owner demonstrated that a POSITA would **not** recognize Shively to disclose a transmitter that would suffer from a problematic increased in PAR. Patent Owner's expert analyzed an 18,000 foot loop because Shively is expressly directed to loops "of the order

18,000 feet or more." Ex. 1011 at 9:65–66. Common sense dictates that Petitioner would submit evidence regarding the 18,000 foot simulation as rebuttal if it was consistent with Petitioner's assertions. Instead, Petitioner submitted irrelevant and improperly new evidence regarding a 12,000 foot simulation. The only conceivable reason Petitioner withheld the 18,000 foot simulation is that it is inconsistent with Petitioner's allegations that Dr. Short is wrong and Shively does have a PAR problem. Accordingly, records of the 18,000 foot simulation should be produced under 37 CFR § 42.51(b)(1)(iii).

III. 18,000 FT. SIMULATION IS "ADDITIONAL DISCOVERY"

The requested discovery should be ordered because it "is in the interests of justice." *Kingston Tech. Co., Inc. v. Catr Co., Ltd.*, IPR2015-00149, Paper 24 at 2, (PTAB June 10, 2015). Further, each of the *Garmin* factors favors this discovery.

Garmin Factor 1: There is more than a chance that the discovery will be useful because it will show whether Dr. Tellado's assertedly necessary simulation supports or negates Petitioner's contention that a POSITA would recognize Shively as suffering from a problematic increase in PAR. *See Corning Inc. v. DSM IP Assets B.V.*, IPR2013-00044, Paper 25 at 4 (P.T.A.B. Jun. 21, 2013) (ordering production of testing documents and the underlying data for the test results).

Garmin Factor 2: Patent Owner is not seeking Petitioner's litigation

positions, nor has Petitioner made such an assertion.

Garmin Factor 3: Patent Owner has no ability to generate equivalent information by other means. Patent Owner should be allowed to use Dr. Tellado's simulation against Petitioner as this is the most powerful evidence for which it cannot deny admissibility or accuracy. Further, although Patent Owner has done its own 18,000 foot simulation and confirmed that Dr. Short was correct, it has no meaningful ability to get that information into the record given the Board's denial of Patent Owner's request for a surreply. When shown this simulation code (Ex. 2010) and results (Ex. 2011) during cross-exam, Dr. Tellado refused to testify regarding its accuracy (Ex. 2013 at 108:7–111:12), although through leading redirect questions he mistakenly concluded it had errors (he did not realize that the code in Ex. 2010 was used to generate the Ex. 2011 graph line only for Scenario 5 (18,000 ft. simulation) and not Scenarios 1–3 and 4 (12,000 ft. simulation)).

Garmin Factor 4: Instructions for the discovery are easily understandable because the scope is narrow and straightforward: Petitioner is being asked to provide each unique copy of the 18,000 foot simulation code and results.

Garmin Factor 5: The requests are not overly burdensome to answer because the scope is narrow and straightforward, and the documents are presumptively in the possession of Petitioner, its expert and/or its IPR counsel.

Dated: July 14, 2017

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Paper No. 46
Entered: February 1, 2018

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CISCO SYSTEMS, INC., DISH NETWORK, LLC,
COMCAST CABLE COMMUNICATIONS, LLC,
COX COMMUNICATIONS, INC.,
TIME WARNER CABLE ENTERPRISES LLC,
VERIZON SERVICES CORP., and ARRIS GROUP, INC.,
Petitioner,

v.

TQ DELTA, LLC,
Patent Owner.

Case IPR2016-01021[1]
Patent 8,718,158 B2

Before SALLY C. MEDLEY, TREVOR M. JEFFERSON, and MATTHEW R. CLEMENTS, *Administrative Patent Judges*.

MEDLEY, *Administrative Patent Judge*.

DECISION
Denying Patent Owner's Rehearing Request
37 C.F.R. § 42.71

[1] DISH Network, L.L.C., who filed a Petition in IPR2017-00255, and Comcast Cable Communications, L.L.C., Cox Communications, Inc., Time Warner Cable Enterprises L.L.C., Verizon Services Corp., and ARRIS Group, Inc., who filed a Petition in IPR2017-00417, have been joined in this proceeding.

I. INTRODUCTION

Pursuant to 37 C.F.R. § 42.71(d), TQ Delta, LLC ("Patent Owner") requests rehearing of our Final Written Decision (Paper 44, "Dec."). Paper 45 ("Req. Reh'g"). Specifically, Patent Owner submits that our construction of "scrambling the phase characteristics of the carrier signals" misapprehends or overlooks certain evidence, that Stopler[2] does not disclose "scrambling the phase characteristics of the carrier signals," that we misapprehended or overlooked certain testimony, and that we misapprehended that Shively[3] would not have an increased or high PAR. Req. Reh'g *passim*.

For the reasons set forth below, Patent Owner's Request for Rehearing is *denied*.

II. STANDARD OF REVIEW

A party requesting rehearing bears the burden of showing that the decision should be modified. 37 C.F.R. § 42.71(d). The party must identify specifically all matters we misapprehended or overlooked, and the place where each matter was addressed previously in a motion, an opposition, or a reply. *Id.* With this in mind, we address the arguments presented by Patent Owner.

III. ANALYSIS

A. "scrambling the phase characteristics of the carrier signals"

Claim 1 recites "a method for scrambling the phase characteristics of the carrier signals, comprising." We adopted Patent Owner's proposed

[2] U.S. Patent No. 6,625,219 B1; issued Sept. 23, 2003 (Ex. 1012) ("Stopler").
[3] U.S. Patent No. 6,144,696; issued Nov. 7, 2000 (Ex. 1011) ("Shively").

construction in part by construing “scrambling the phase characteristics of the carrier signals” to mean “adjusting the phases of a plurality of carriers in a single multicarrier symbol.” Dec. 8–11. We did not add to that construction “by pseudo-randomly varying amounts” because Patent Owner did not show why that additional language should be included for the broadest reasonable construction of the term “scrambling the phase characteristics of the carrier signals.” *Id*. Patent Owner argues that our construction is overly broad because it encompasses adjusting the phases of every carrier in the single multicarrier symbol by the same amount. Req. Reh’g. 2–3. Such an adjustment, according to Patent Owner, would not reduce peak-to-average power ratio (“PAR”), which the parties and the panel all agree scrambling must do. *Id.* at 3–6. “The FWD misapprehends or overlooks that, under any proper construction, there must at a minimum be *varying amounts* by which the phases are adjusted within a single multicarrier symbol (*i.e.*, *from carrier-to-carrier*) such that PAR is reduced.” *Id.* at 2.

Patent Owner presents arguments not presented previously. We could not have overlooked or misapprehended those arguments presented for the first time in the rehearing request. Importantly, Patent Owner argues now for the first time that for any proper construction “there must at a minimum be varying amounts by which the phases are adjusted within a single multicarrier symbol (i.e., from carrier-to-carrier) such that PAR is reduced.” *Id.* at 2. This proposed construction differs from Patent Owner’s original proposed construction which included “by pseudo-randomly varying amounts.” Absent from the new proposed construction is the term “pseudo-randomly.”

In any event, it is clear from the Decision that we construed the totality of claim 1, for example, as requiring varying the amount by which the phase of each carrier is adjusted. *See, e.g.*, Dec. 28. Accordingly, even if we were to adopt Patent Owner's new proposed construction, it would not change the way we applied the prior art to the claim language as a whole.

B. Stopler's Single-Carrier Embodiment

Patent Owner argues that Stopler's QAM Mapper and Phase Scrambler 82 "must be compatible with single-carrier CDMA" because Stopler teaches that its output can, in one embodiment, be provided to a CDMA modulator. Req. Reh'g. 7–8. Patent Owner concludes that Stopler's phase scrambling "must have a different purpose than the claimed phase scrambling because [it] . . . cannot reduce PAR." *Id.* at 8.

We addressed this argument and found it unpersuasive. Dec. 23–28. Mere disagreement with the Board's conclusion is not a proper basis for rehearing. It is not an abuse of discretion to have made a conclusion with which a party disagrees.

C. Allegedly Misapprehended or Overlooked Testimony

Patent Owner quotes pages 25 to 26 of our Decision and argues that "there are several inaccuracies." Req. Reh'g 8–12. These arguments are based, in part, on a mischaracterization of our claim construction as *requiring* the same amount of rotation of the phase of each of the QAM symbols in a DMT symbol. *See, e.g.*, *id.* at 9 ("First, a DMT symbol cannot be phase scrambled as that term is used in the claims by having its component QAM symbols rotated by the *same* amount."), 9 ("as interpreted in the FWD ('i.e., rotates by the same amount, the phase of a plurality of QAM symbols.')."). Our construction of "scrambling the phase

characteristics of the carrier signals" does not *require* rotating by the same amount. And as we applied the prior art, to the totality of the claim language, it is clear that we construed the totality of the claim language to require the phases of the carriers of the multi-carrier signal be rotated by varying amounts. For example, our Decision states

> Stopler further teaches that, "a phase scrambling sequence is applied to the output symbols," including "all symbols, not just the overhead symbols." *Id*. at 12:25–28. Patent Owner's expert, Dr. Short, agreed that Stopler is referring to phase scrambling QAM symbols. Reply 16–17 (citing Ex. 1027 (Tellado Dep.), 54:17–55:3, 55:19–24, 58:6–8, 59:9–12, 60:15–22). Stopler further teaches that a "scrambling sequence may be generated by a pseudorandom generator" that generates pairs whose sum "is used to select the amount of rotation to be applied to the symbol," singular; not "symbols" plural. Ex. 1012, 12:28–36. Thus, the most intuitive reading of Stopler supports Petitioner's contention that QAM Mapper and Phase Scrambler 82 determines an amount of rotation and rotates the phase of a single QAM symbol by that amount.

Dec. 26.

Patent Owner also objects to our characterization of Dr. Short's testimony as "admit[ing] that Stopler does not describe phase scrambling DMT symbols" (Dec. 25 (citing Ex. 1027, 60:11–14)). Req. Reh'g 9 (regarding Ex. 1027, 60:11–14). That testimony is as follows:

> Q. Well, you would agree with me that [Stopler] doesn't expressly teach applying the phase scrambler to the DMT as a whole?
>
> A. I would agree with that.

Ex. 1027, 60:11–14. We acknowledge that Dr. Short testified that he *understands* Stopler to be rotating all of the QAM symbols within a DMT symbol by the same amount, but the point made in our Decision

remains: Dr. Short clearly conceded, however, that Stopler does not *expressly teach* applying the phase scrambler to the DMT symbol as a whole. Dec. 25 (citing Ex. 1027, 60:11–14).

Patent Owner also argues that we misapprehended its argument that Stopler would adjust the phases of QAM symbols *over time* in order to reduce narrowband noise. Req. Reh'g 10 (citing PO Resp. 39 ("According to a second narrowband-noise-reducing technique, Stopler addresses narrowband noise at the frequency of an overhead pilot carrier by scrambling the phase of the pilot carrier over time from one DMT symbol to the next, *i.e.*, by ***inter***-symbol phase scrambling. *See* Ex. 2003 at ¶ 82."). As we noted in our Decision, however, Stopler teaches and Petitioner relies "not just on the scrambling of 'overhead signals, such as pilot tones,' (Pet. 13) but on the scrambling of *all* QAM symbols. Because neither Petitioner's argument nor Stopler's teaching of phase scrambling is limited to pilot tones, Patent Owner's argument is not persuasive." Dec. 27.

Patent Owner also argues that we misapprehended its burden by noting that "Patent Owner identifies nothing in Stopler to suggest that, in an alternative embodiment with a multicarrier modulator, QAM Mapper and Phase Scrambler 82 do not supply a plurality of phase-scrambled QAM symbols for modulation onto the plurality of carriers in the, e.g., DMT symbol." Req. Reh'g 11 (quoting Dec. 25–26). Petitioner has the burden of persuasion to prove unpatentability by a preponderance of the evidence. *See* 35 U.S.C. § 316(e); *Dynamic Drinkware, LLC v. Nat'l Graphics, Inc.*, 800 F.3d 1375, 1379 (Fed. Cir. 2015). For this element, we explained how Petitioner satisfied that burden based, *inter alia*, on express disclosure in Stopler. Dec. 26–27. The sentence to which Patent Owner objects merely

notes that, even assuming Stopler works as Patent Owner argues in an embodiment with a single-carrier modulator, that does not persuasively rebut the express disclosure upon which Petitioner relies. Accordingly, we are not persuaded that we misapprehended Patent Owner's burden.

Patent Owner also argues it was denied the opportunity to file a sur-reply. Req. Reh'g. 11–12. Patent Owner was, however, granted an opportunity to identify allegedly new arguments and evidence in Petitioner's Reply (Paper 25), and we considered the identified portions when reaching our Decision (Dec. 22 n.8). Although the "listing" format required Patent Owner to be efficient in its identification and required Petitioner to be efficient in its responsive paper, these papers provided "the information necessary to make a reasoned decision" (*Ultratec, Inc. v. CaptionCall, LLC*, 872 F.3d 1267, 1273 (Fed. Cir. 2017)) about whether the arguments and evidence raised in reply were outside the scope of a proper reply.

D. Shively's PAR

Finally, Patent Owner argues that we misapprehended or overlooked its argument that Shively's PAR would not be so "increased" or "high" that it resulted in clipping, as would be needed before a person of ordinary skill in the art had reason to modify Shively. Req. Reh'g 12–15. We addressed this argument and found it unpersuasive. Dec. 30–31. Mere disagreement with the Board's conclusion is not a proper basis for rehearing. It is not an abuse of discretion to have made a conclusion with which a party disagrees.

Moreover, Patent Owner alleges that "the FWD characterizes Shively as having a 'high' or 'increased' PAR." Req. Reh'g. 14 (citing Dec. 30). That is false. Our Decision states that it is undisputed that Shively's technique "will increase PAR" (Dec. 30–31), but does not characterize

Shively as having a "high" or "increased" PAR.[4] Our Decision relies upon page 28 of Patent Owner's Response (Paper 15), which concedes that "Shively's 'spreading' technique will contribute a small uptick in clipping probability." Patent Owner does not dispute, in its Request for Rehearing, Shively's technique *increases* PAR.

With respect to Patent Owner's argument that "there is no PAR *problem* presented by Shively" (Req. Reh'g. 14) and "the only PAR problem in this case relates to clipping" (*id.* at 15), we considered that argument and found it unpersuasive. Dec. 30–31. As we noted, "Petitioner's reason to combine does not depend on the PAR increase exceeding some specific numeric threshold," "there also is no dispute that equipment designed to handle a higher PAR can be larger, more expensive, and more power hungry than equipment designed to handle a lower PAR," and, therefore, "a person of ordinary skill in the art . . . would have been motivated to reduce PAR regardless of whether Shively's technique resulted in clipping." *Id*. In other words, as we explained in our Decision, Shively's PAR need not result in clipping in order to motivate a person of ordinary skill in the art because we are persuaded such a person would have been motivated sufficiently to reduce PAR by the benefit of being able to use smaller, less expensive, less power hungry components.

[4] In a sentence summarizing Petitioner's position, our Decision states, "*Petitioner alleges* that Shively's proposed system would have an 'increased' or 'high' PAR." Dec. 30 (quoting Pet. 14–15) (emphasis added). It should be obvious, however, that a summary of Petitioner's allegation is not a characterization by the panel.

IV. ORDER

Accordingly, it is ORDERED that Patent Owner's Request for Rehearing is *denied*.

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UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CISCO SYSTEMS, INC., DISH NETWORK, LLC,
COMCAST CABLE COMMUNICATIONS, LLC,
COX COMMUNICATIONS, INC.,
TIME WARNER CABLE ENTERPRISES LLC,
VERIZON SERVICES CORP., and ARRIS GROUP, INC.,
Petitioners,

v.

TQ DELTA, LLC
Patent Owner

Case No. IPR2016-01021[1]
Patent No. 8,718,158

PATENT OWNER'S NOTICE OF APPEAL

[1] DISH Network, L.L.C., who filed a Petition in IPR2017-00255, and Comcast Cable Communications, L.L.C., Cox Communications, Inc., Time Warner Cable Enterprises L.L.C., Verizon Services Corp., and ARRIS Group, Inc., who filed a Petition in IPR2017-00417, have been joined in this proceeding.

Pursuant to 35 U.S.C. §§ 141, 142, and 319, 37 C.F.R. §§ 90.2, 90.3, and 104.2, and Rule 4(a) of the Federal Rules of Appellate Procedure, Patent Owner TQ Delta, LLC ("Patent Owner") hereby appeals to the United States Court of Appeals for the Federal Circuit from the Decision Denying Request for a Rehearing (Paper 46) entered by the Patent Trial and Appeal Board on February 1, 2018 and the Final Written Decision (Paper 44) entered by the Patent Trial and Appeal Board on October 26, 2017, and all rulings leading up to those decisions.

In particular, and in accordance with 37 C.F.R. § 90.2(a)(3)(ii), Patent Owner identifies at least the following issues on appeal:

- The Board's finding that Claims 1, 2, 4, 15, 16, and 18 of U.S. Patent No. 8,718,158 are unpatentable as obvious over Shively and Stopler;
- The Board's finding that Claims 3, 5, 14, 17, 19, and 28-30 of U.S. Patent No. 8,718,158 are unpatentable as obvious over Shively, Stopler, and Gerszberg;
- The Board's finding that Claims 6, 9, 10, 12, 20, 23, 24, and 26 of U.S. Patent No. 8,718,158 are unpatentable as obvious over Shively, Stopler, and Bremer;
- The Board's finding that Claims 8, 11, 13, 22, 25, and 27 of U.S. Patent No. 8,718,158 are unpatentable as obvious over Shively, Stopler, Bremer, and Gerszberg;

- The Board's finding that Claims 7 and 21 of U.S. Patent No. 8,718,158 are unpatentable as obvious over Shively, Stopler, Bremer, and Flammer.
- The Board's claim construction; and
- Any Board finding, determination, judgment, or order supporting or related to the aforementioned issues as well as all other issues decided adversely to Patent Owner in any orders, decisions, ruling, and opinions.

Patent Owner is concurrently filing a copy of this Notice of Appeal with the Director of the United States Patent and Trademark Office and the Patent Trial and Appeal Board, and a copy of the same, along with the required fees, with the United States Court of Appeals for the Federal Circuit.

Respectfully submitted,

Dated: April 2, 2018

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CERTIFICATE OF FILING

The undersigned hereby certifies that, in addition to being electronically filed through PTAB E2E, a true and correct copy of the above-captioned **NOTICE OF APPEAL** is being filed by hand with the Director on April 2, 2018, at the following address:

Director of the U.S. Patent & Trademark Office
c/o Office of the General Counsel, 10B20
Madison Building East
600 Dulany Street
Alexandria, VA 22314

The undersigned also hereby certifies that a true and correct copy of the above-captioned **NOTICE OF APPEAL** and the filing fee is being filed via CM/ECF with the Clerk's Office of the United States Court of Appeals for the Federal Circuit on April 2, 2018.

Dated: April 2, 2018

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CERTIFICATE OF SERVICE

The undersigned hereby certifies that the foregoing **NOTICE OF APPEAL** was served electronically via email on April 2, 2018 in its entirety on the following:

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Paper 44
Entered: October 26, 2017

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CISCO SYSTEMS, INC., DISH NETWORK, LLC,
COMCAST CABLE COMMUNICATIONS, LLC,
COX COMMUNICATIONS, INC.,
TIME WARNER CABLE ENTERPRISES LLC,
VERIZON SERVICES CORP., and ARRIS GROUP, INC.,
Petitioner,

v.

TQ DELTA, LLC,
Patent Owner.

Case IPR2016-01021[1]
Patent 8,718,158 B2

Before SALLY C. MEDLEY, TREVOR M. JEFFERSON, and,
MATTHEW R. CLEMENTS, *Administrative Patent Judges.*

MEDLEY, *Administrative Patent Judge*.

FINAL WRITTEN DECISION
35 U.S.C. § 318(a) and 37 C.F.R. § 42.73

[1] DISH Network, L.L.C., who filed a Petition in IPR2017-00255, and Comcast Cable Communications, L.L.C., Cox Communications, Inc., Time Warner Cable Enterprises L.L.C., Verizon Services Corp., and ARRIS Group, Inc., who filed a Petition in IPR2017-00417, have been joined in this proceeding.

I. INTRODUCTION

In this *inter partes* review, instituted pursuant to 35 U.S.C. § 314, Cisco Systems, Inc. ("Petitioner") challenges claims 1–30 ("the challenged claims") of U.S. Patent No. 8,718,158 B2 (Ex. 1001, "the '158 patent"), owned by TQ Delta, LLC ("Patent Owner"). We have jurisdiction under 35 U.S.C. § 6. This Final Written Decision is entered pursuant to 35 U.S.C. § 318(a) and 37 C.F.R. § 42.73. For the reasons discussed below, Petitioner has shown by a preponderance of the evidence that the challenged claims are unpatentable. Patent Owner's Motion to Exclude is *dismissed*.

A. Procedural History

Petitioner filed a Petition for *inter partes* review of claims 1–30 of the '158 patent. Paper 2 ("Pet."). Patent Owner filed a Preliminary Response. Paper 6 ("Prelim. Resp."). On November 4, 2016, we instituted an *inter partes* review of claims 1–30 of the '158 patent on the following grounds (Paper 7 ("Dec.")):

References	Basis	Claims Challenged
Shively,[2] and Stopler[3]	§ 103(a)	1, 2, 4, 15, 16, and 18
Shively, Stopler, and Gerszberg[4]	§ 103(a)	3, 5, 14, 17, 19, and 28–30
Shively, Stopler, and Bremer[5]	§ 103(a)	6, 9, 10, 12, 20, 23, 24, and 26
Shively, Stopler,	§ 103(a)	8, 11, 13, 22, 25, and 27

[2] U.S. Patent No. 6,144,696; issued Nov. 7, 2000 (Ex. 1011) ("Shively").
[3] U.S. Patent No. 6,625,219 B1; issued Sept. 23, 2003 (Ex. 1012) ("Stopler").
[4] U.S. Patent No. 6,424,646 B1; issued July 23, 2002 (Ex. 1013) ("Gerszberg").
[5] U.S. Patent No. 4,924,516; issued May 8, 1990 (Ex. 1017) ("Bremer").

References	Basis	Claims Challenged
Bremer, and Gerszberg		
Shively, Stopler, Bremer, and Flammer[6]	§ 103(a)	7 and 21

Thereafter, Patent Owner filed a Patent Owner Response ("PO Resp."). Paper 15. Petitioner filed a Reply to the Patent Owner Response ("Pet. Reply"). Paper 20. Pursuant to an Order (Paper 24), Patent Owner filed a listing of alleged statements and evidence in connection with Petitioner's Reply deemed to be beyond the proper scope of a reply. Paper 25. Petitioner filed a response to Patent Owner's listing. Paper 32.

Patent Owner filed a Motion to Exclude, Paper 31 ("PO Mot. Exc."), Petitioner filed an Opposition, Paper 36 ("Pet. Opp. Mot. Exc."), and Patent Owner filed a Reply, Paper 40. Patent Owner filed a Motion for Observation, Paper 30 ("PO Mot. Obs.") and Petitioner filed a Response to the Motion for Observation, Paper 37 ("Pet. Resp.").

We held a consolidated hearing on August 3, 2017, for this case and related Case IPR2016-01020, and a transcript of the hearing is included in the record. Paper 42 ("Tr.").

B. Related Proceedings

The parties indicate that the '158 patent is the subject of several pending judicial matters. Pet. 1; Paper 5, 2–3.

C. The '158 Patent (Ex. 1001)

The '158 patent relates to multicarrier communications systems that lower the peak-to-average power ratio (PAR) of transmitted signals.

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[6] U.S. Patent No. 5,515,369; issued May 7, 1996 (Ex. 1019) ("Flammer").

Ex. 1001, 1:28–31. A value is associated with each carrier signal, and a phase shift is computed for each carrier signal based on the value associated with that carrier signal. *Id.* at 2:38–41. The value is determined independent of the input bit value carried by the carrier signal. The computed phase shift value is combined with the phase characteristic of that carrier signal to substantially scramble the phase characteristics of the carrier signals. *Id.* at 2:38–45. Figure 1 illustrates the multicarrier communication system and is reproduced below:

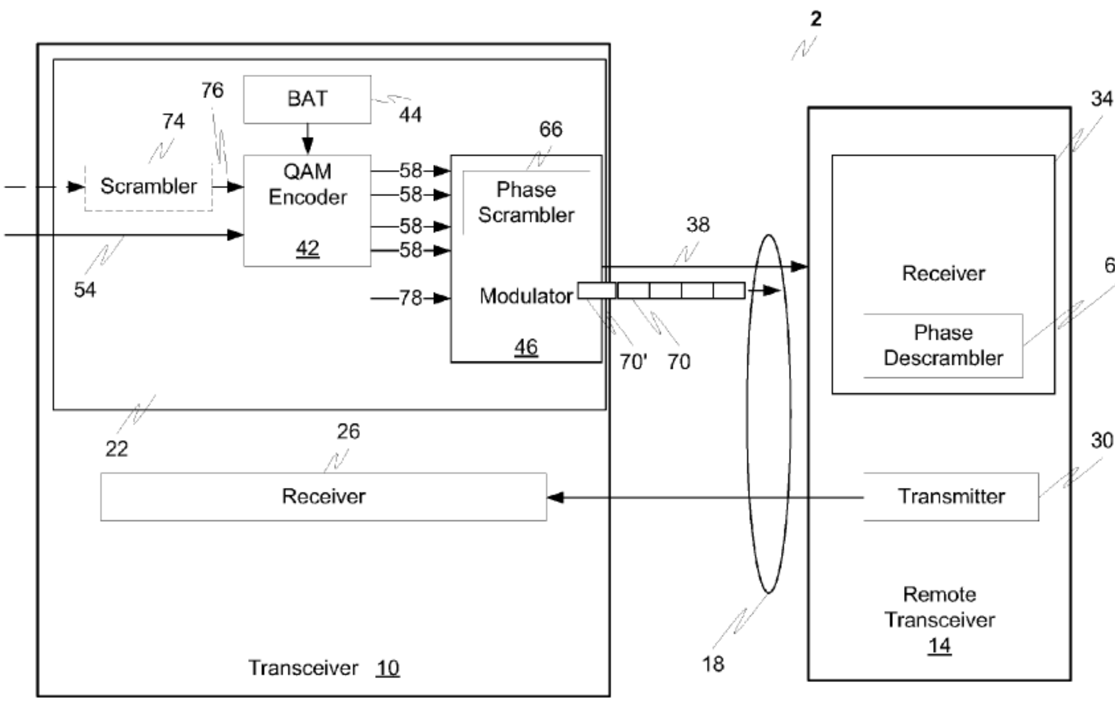


FIG. 1

Figure 1 illustrates the multicarrier communication system, digital subscriber line (DSL) communication system 2, which includes discrete multitoned (DMT) transceiver 10 communicating with remote transceiver 14 over communication channel 18 using transmission signal 38 having a plurality of carrier signals. *Id.* at 3:27–31. DMT transceiver 10 includes

DMT transmitter 22 and DMT receiver 26. *Id.* at 3:31–32. Remote transceiver also includes transmitter 30 and receiver 34. *Id.* at 3:32–34. DMT transmitter 22 transmits signals over communication channel 18 to receiver 34. *Id.* at 3:40–42.

DMT transmitter 22 includes a quadrature amplitude modulation (QAM) encoder 42, modulator 46, bit allocation table (BAT) 44, and phase scrambler 66. *Id.* at 3:53–56. QAM encoder 42 has a single input for receiving serial data bit stream 54 and multiple parallel outputs to transmit QAM symbols 58 generated by QAM encoder 42 from bit stream 54. *Id.* at 3:65–4:1. Modulator 46 provides DMT modulation functionality and transforms QAM symbols 58 into DMT symbols 70. *Id.* at 4:12–14. Modulator 46 modulates each carrier signal with a different QAM symbol 58, and, therefore, this modulation results in carrier signals having phase and amplitude characteristics based on QAM symbol 58. *Id.* at 4:15–18. Modulator 46 also includes phase scrambler 66 that combines a phase shift computed for each QAM-modulated carrier signal with the phase characteristics of that carrier signal. *Id.* at 4:31–34.

D. Illustrative Claim

Petitioner challenges claims 1–30 of the ’158 patent. Claims 1 and 15 are independent claims. Claims 2–14 and 29 depend, either directly or indirectly, from claim 1, and claims 16–28 and 30 depend, either directly or indirectly, from claim 15. Claim 1 is reproduced below.

> 1. In a multicarrier modulation system including a first transceiver in communication with a second transceiver using a transmission signal having a plurality of carrier signals for modulating a plurality of data bits, each carrier signal having a phase characteristic associated with at least one bit of the

> plurality of data bits, a method for scrambling the phase characteristics of the carrier signals comprising:
>
> transmitting the plurality of data bits from the first transceiver to the second transceiver;
>
> associating a carrier signal with a value determined independent of any bit of the plurality of data bits carried by the carrier signal, the value associated with the carrier signal determined by a pseudo-random number generator;
>
> determining a phase shift for the carrier signal at least based on the value associated with the carrier signal;
>
> modulating at least one bit of the plurality of data bits on the carrier signal; and
>
> modulating the at least one bit on a second carrier signal of the plurality of carrier signals.

Ex. 1001, 10:59–11:11.

II. ANALYSIS

A. Principles of Law

To prevail in its challenge to Patent Owner's claims, Petitioner must demonstrate by a preponderance of the evidence that the claims are unpatentable. 35 U.S.C. § 316(e); 37 C.F.R. § 42.1(d). A claim is unpatentable under 35 U.S.C. § 103(a) if the differences between the claimed subject matter and the prior art are such that the subject matter, as a whole, would have been obvious at the time of the invention to a person having ordinary skill in the art. *KSR Int'l Co. v. Teleflex, Inc.*, 550 U.S. 398, 406 (2007). The question of obviousness is resolved on the basis of underlying factual determinations including: (1) the scope and content of the prior art; (2) any differences between the claimed subject matter and the

prior art; (3) the level of ordinary skill in the art; and (4) objective evidence of nonobviousness. *Graham v. John Deere Co. of Kansas City*, 383 U.S. 1, 17–18 (1966).

In that regard, an obviousness analysis "need not seek out precise teachings directed to the specific subject matter of the challenged claim, for a court can take account of the inferences and creative steps that a person of ordinary skill in the art would employ." *KSR*, 550 U.S. at 418; *see also Translogic Technology, Inc.*, 504 F.3d 1249, 1259, and 1262 (Fed. Cir. 2007).

B. Level of Ordinary skill in the Art

Citing its declarant, Dr. Jose Tellado, Petitioner contends that a person having ordinary skill in the art at the time of the invention would have had (1) a Master's degree in Electrical and/or Computer Engineering, or equivalent training, and (2) approximately five years of experience working with multicarrier communications systems. Pet. 10–11; Ex. 1009 ¶ 18. Petitioner also contends that "[l]ack of work experience can be remedied by additional education, and vice versa." Pet. 11.

Patent Owner's expert, Dr. Robert Short indicated that for purposes of the proceeding he adopts Dr. Tellado's definition of a person of ordinary skill in the art. Ex. 2003 ¶ 16. For purposes of this Decision, we adopt Petitioner's proposed definition, and further find that the level of ordinary skill in the art is reflected by the prior art of record. *See Okajima v. Bourdeau*, 261 F.3d 1350, 1355 (Fed. Cir. 2001); *In re GPAC Inc.*, 57 F.3d 1573, 1579 (Fed. Cir. 1995); *In re Oelrich*, 579 F.2d 86, 91 (CCPA 1978).

C. Claim Interpretation

The Board interprets claims of an unexpired patent using the broadest reasonable construction in light of the specification of the patent in which they appear. *See* 37 C.F.R. § 42.100(b); *see also* Office Patent Trial Practice Guide, 77 Fed. Reg. at 48,766. Under the broadest reasonable construction standard, claim terms are given their ordinary and customary meaning, as would be understood by one of ordinary skill in the art in the context of the entire disclosure. *In re Translogic*, 504 F.3d at 1257.

Petitioner proposes constructions for the following claim terms: "multicarrier" and "transceiver." Pet. 8–9. In our Decision to Institute, we interpreted the term "transceiver" to mean "a device, such as a modem, with a transmitter and receiver," but determined that it was not necessary to interpret the term "multicarrier." Dec. 6–7. Neither party has indicated that our determinations were improper and we do not perceive any reason or evidence that now compels any deviation from our initial determinations. PO Resp. 13–14; Pet. Reply 7–8. Accordingly, the construction of transceiver to mean "a device, such as a modem, with a transmitter and receiver" applies to this Decision. Dec. 7. For purposes of this decision, we find it necessary to construe "scrambling the phase characteristics of the carrier signals" found in claim 1.

Scrambling the Phase Characteristics of the Carrier Signals

The preamble of claim 1 recites a transmission signal with a plurality of carrier signals where each carrier signal has a phase characteristic and "a method for *scrambling the phase characteristics of the carrier signals*, comprising." (Emphasis added). Patent Owner argues that the italicized language should be interpreted to mean "adjusting the phases of a plurality

of carriers in a single multicarrier symbol by pseudo-randomly varying amounts." PO Resp. 14–19. Petitioner argues that the phrase needs no interpretation, since the prior art relied upon uses the same "phase scrambling" terminology to describe pseudo-random phase changes. Pet. Reply 7 (citing Ex. 1012, 12:24–31). Additionally, Petitioner argues, without any other explanation, that "the Board should not adopt TQ Delta's proposed construction." *Id*. During oral argument, however, counsel for Petitioner reiterated that it is Petitioner's position that no construction of the term is necessary, because "[r]egarding [P]atent [O]wner's proposal of the construction, we believe that is exactly how Stopler is describing this phase scrambler as operating." Tr. 18:23–19:5.

The phrase "scrambling the phase characteristics of the carrier signals" is recited in the preamble of claim 1. Although neither party explicitly explains why the preamble of claim 1 is limiting, both parties implicitly contend that the preamble is limiting. For purposes of this decision, we determine that the preamble is limiting. We further find it helpful to our decision and analysis to interpret the phrase in order to understand the parties' positions with respect to how the prior art reference Stopler meets the phrase.

Patent Owner argues that "scrambling the phase characteristics of the carrier signals" should be construed to mean "adjusting the phases of a plurality of carriers in a single multicarrier symbol by pseudo-randomly varying amounts." PO Resp. 14. Patent Owner contends that the construction is supported by the specification of the '158 patent and clarifies that the claimed phase scrambling "must be performed amongst the individual carrier phases in a single multicarrier symbol" and is not met if

the phase adjustment only occurs over time from one symbol to the next. PO Resp. 14 (citing Ex. 2003 ¶ 37).

In support of its proposed interpretation, Patent Owner argues that the ’158 patent describes that each of the plurality of carriers (of a multicarrier signal) corresponds to a different QAM symbol. PO Resp. 15 (citing Ex. 1001, 4:15–16). Patent Owner further argues that each carrier (or QAM symbol) has its own phase or phase characteristic, and that the combination of the carriers (or QAM symbols) is referred to as a DMT symbol. PO Resp. 16 (citing Ex. 1001, 4:9–11, 9:8–9; Ex. 2003 ¶ 39). Patent Owner further contends that the ’158 patent describes that a “phase scrambler” scrambles phases or phase characteristics of carriers within a single DMT symbol, and that PAR in the transmission signal is reduced by adjusting the carrier phases within a single DMT symbol. PO Resp. 16 (citing Ex. 1001, 6:32–8:13; Ex. 2003 ¶ 39). PAR, Patent Owner contends, would not be reduced if carrier phases were only adjusted from one symbol to the next. PO Resp. 16 (Ex. 2003 ¶¶ 41–42).

Based on the record before us, we agree with Patent Owner’s proposed construction as far as meaning “adjusting the phases of a plurality of carriers in a single multicarrier symbol.” PO Resp. 14. Patent Owner, however, provides no persuasive reasoning for also adding to that construction “by pseudo-randomly varying amounts.” *Id.* Rather, Patent Owner merely contends that (1) in a corresponding district court matter, the court construed the phrase to mean “adjusting the phase characteristics of the carrier signals by pseudo-randomly varying amounts;” (2) during prosecution of a child application to the ’158 patent, the applicant explained that a “scrambler” operates by pseudo-randomly selecting bits to invert; and

(3) there was no fundamental disagreement between parties that scrambling involves adjusting the phase characteristic of a carrier signal by pseudo-randomly varying amounts. PO Resp. 16–17. Patent Owner's explanation for why we should add "by pseudo-randomly varying amounts" to its proposed construction is conclusory. *Id.* at 17. We interpret claims using the broadest reasonable construction in light of the specification of the involved patent. That standard is not the same as the standard used in district court. Patent Owner, however, provides no explanation for why we should apply the district court construction, which is not necessarily the same as used before us, here. Moreover, Patent Owner does not explain why statements made during prosecution of a child application for the term "scrambler" is relevant to how we should interpret the disputed phrase that does not even contain the term "scrambler" in it. *Id.* at 16. In summary, Patent Owner's arguments are conclusory.

For all of the above reasons, and for purposes of this decision, we determine that "scrambling the phase characteristics of the carrier signals" means "adjusting the phases of a plurality of carriers in a single multicarrier symbol."

D. Asserted Obviousness over Shively and Stopler

Petitioner contends that claims 1, 2, 4, 15, 16, and 18 are unpatentable under 35 U.S.C. § 103(a) as obvious over Shively and Stopler. Pet. 11–32. We have reviewed Petitioner's showing identifying where each limitation allegedly appears in Shively and Stopler, along with the testimony of Petitioner's declarant, Dr. Jose Tellado. *Id.* (citing Ex. 1009). We also have reviewed Patent Owner's assertions and evidence, including the testimony of Dr. Robert Short, as to why Petitioner's showing is deficient.. PO Resp.

Shively (Ex. 1011)

Shively discloses discrete multitoned transmission (DMT) of data by digital subscriber loop (DSL) modems and the allocation of bits to the discrete multitones. Ex. 1011, 1:5–8. Bit allocation is performed to optimize throughput within aggregate power and power spectral density mask limits. *Id.* at 4:17–19. The system includes a transmitting modem and a receiving modem connected by a cable having four twisted pairs of conductors. *Id.* at 9:63–65. The modems include a source encoder, a channel decoder, and a digital modulator to take in and transmit data from a data source. *Id.* at 10:9–12. The modems also include a digital demodulator, a channel decoder, and a source decoder to receive the data and supply it to a data sink. *Id.* at 10:12–14. The source encoder compresses data, applies the compressed data to the channel decoder, which performs error correction. *Id.* at 10:15–19. The error corrected data is applied to the digital modulator, which acts as the interface with the communication channel. *Id.* at 10:15–22. The digital demodulator constructs a data stream from the modulated signal and applies it to the channel decoder, which performs error correction, and then applies the corrected data to the source decoder, which decompresses the data. *Id.* at 10:22–26.

In the QAM multitoned modulation, the spectrum is broken into multiple sub-bands or QAM channels. *Id.* at 10:27–29. The digital modulator generates N QAM signal tones, one for each QAM channel. *Id.* at 10:29–30. The serial stream is segmented in to N frames, each having allocated to it k_i bits of data. *Id.* at 10:30–31. The multi-carrier modulator

generates N QAM tones, one for each channel, at the same symbol rate but with a respective constellation for each channel. *Id.* at 10:35–37.

Stopler (Ex. 1012)

Stopler discloses a method and apparatus for encoding/framing a data stream of multitoned modulated signals to improve impulse burst immunity. Ex. 1012, 1:8–11. The encoding/framing scheme allows efficient operation in multipoint to point channels affected by ingress and impulsive interference. *Id.* at 5:11–14. Two dimensional interleaving is performed, with one dimension being time and the other dimension being frequency (tones or sub-channels). *Id.* at 5:18–20. Stopler further discloses a diagonalization scheme, where data packets are spread over time in a diagonal fashion, such that an impulse noise affects more than one user's packets, with the effect on each being reduced. *Id.* at 5:64–67. A code having lower redundancy can be used since the amount of corruption expected in one user's data packet will be reduced. *Id.* at 5:67–6:3.

Figure 5 of Stopler is reproduced below.

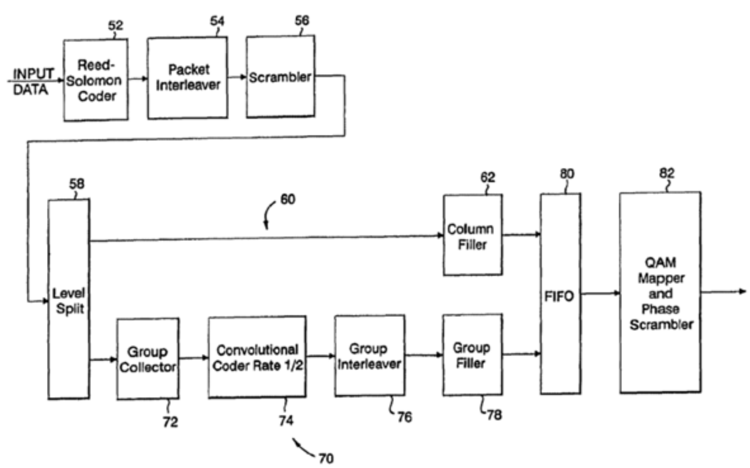


FIG. 5

As shown above, Figure 5 of Stopler, input data, in the form of data packets, is input to an RS coder 52. *Id.* at 8:55–57. Data output by RS coder 52 is input to interleaver 54. *Id.* at 9:8–10. The output of interleaver 54 is rearranged into a serial bit stream and then scrambled in scrambler 56, which is used to randomize coded and interleaved data. *Id.* at 9:34–37. Data output by scrambler 56 is divided by level splitter 58 into two levels of the TCM encoder. Splitter 58 divides serial bit stream into a group of data bits to be processed by lower level 70, and the remaining data bits to be processed by upper level 60. *Id.* at 9:48–55. In lower level 70 of TCM encode, data is collected into groups by group collector 72, which is input to coder 74, then group interleaver 76 and then group filler 78. *Id.* at 10:40–11:18. The outputs of upper stream 60 and lower stream 70 are combined into m-tuples (QAM symbols) and temporarily stored in FIFO buffer 80, which then delivers data to a QAM mapper 82. *Id.* at 11:51–57.

The input to QAM mapper 82 is data in the form of m-tuples which are mapped into QAM symbols. *Id.* at 12:21–22. To randomize the overhead channel symbols, a phase scrambling sequence is applied to the output symbols. For example, the phase scrambling sequence may be generated by a pseudo-random generator composed of a linear feedback shift register of length 21, and initialized by a user programmable seed. *Id.* at 12:24–31. Consecutive output pairs from the pseudo-random generator are converted into numbers 2a+b and the sum (2a+b) is used to select the amount of rotation to be applied to the symbol according to the following table below:

2a + b		Phase Rotation
0	→	0
1	→	$+\pi/2$
2	→	π
3	→	$-\pi/2$

Id. at 12:31–45. The output from the QAM mapper 82 is provided to a modulator (not shown) which implements the particular signal modulation desired, e.g., VCMT, CDMA, etc. *Id.* at 12:55–57.

Analysis

Petitioner contends that claims 1, 2, 4, 15, 16, and 18 would have been obvious over Shively and Stopler. Pet. 11–32. Patent Owner's arguments are directed to whether a person of ordinary skill in the art would have combined Shively and Stopler and whether Stopler describes phase scrambling. PO Resp. 45–58.

Claim 1 recites "[i]n a multicarrier modulation system including a first transceiver in communication with a second transceiver." Petitioner contends that Shively and Stopler each describe this limitation. For example, and with respect to Shively, Petitioner argues that Shively describes a discrete multitoned transmission (DMT) of data (a multicarrier modulation system) by digital subscriber loop (DSL) modems (illustrated in Figure 2 as a transmitting modem 31 and a receiving mode 32). Pet. 17 (citing Ex. 1011, 1:5–7, 9:42, 9:63–64, and Fig. 2; Ex. 1009, 31–32).[7] We are persuaded by Petitioner's showing and find that Shively's modem 31 is a first transceiver in communication with a second transceiver 32 and that the

[7] In the Petition, Petitioner references page numbers of Dr. Tellado's Declaration, as opposed to paragraph numbers. Citations are to page numbers, unless otherwise indicated by use of the paragraph symbol ("¶").

two transceivers communicate using discrete multitoned transmission (DMT) of data, and thus are in a multicarrier modulation system.

Claim 1 further recites "using a transmission signal having a plurality of carrier signals for modulating a plurality of data bits." Petitioner contends that Shively and Stopler each render obvious this phrase. For example, and with respect to Shively, Petitioner contends that Shively describes a transmitting modem that receives digital data from a data source and modulates separate carriers to represent the digital data, which results in a modulated signal sent to a receiving modem. Pet. 19 (citing Ex. 1011, 5:22–26). Petitioner further contends that Shively describes that the available frequency spectrum is divided into multiple QAM channels, which a person of ordinary skill in the art would have understood to be a "plurality of carrier signals" for modulating "a plurality of data bits." Pet. 19 (citing Ex. 1011, 5:47, 5:52; Ex. 1009, 35–36). We are persuaded by Petitioner's showing, which we adopt as our own findings and conclusions, that Shively renders obvious "using a transmission signal having a plurality of carrier signals for modulating a plurality of data bits."

Claim 1 recites "each carrier signal having a phase characteristic associated with at least one bit of the plurality of data bits." Petitioner contends that Shively and Stopler each render obvious this phrase. For example, and with respect to Shively, Petitioner contends that Shively describes transmitting data bits using quadrature amplitude modulation (QAM) and that QAM produces a signal whose phase and amplitude convey encoded k-bits of information. Pet. 20 (citing Ex. 1011, 1:29–30). Petitioner further contends that a person having ordinary skill in the art would have understood that the phase of a signal used in QAM to convey

bits is a phase characteristic as claimed. Pet. 20 (citing Ex. 1001, 1:43–44; Ex. 1009, 38). We are persuaded by Petitioner's showing, which we adopt as our own findings and conclusions, that Shively describes "each carrier signal having a phase characteristic associated with at least one bit of the plurality of data bits."

Claim 1 further recites a "method for scrambling the phase characteristics of the carrier signals." Petitioner contends that Stopler describes a phase scrambler that applies a phase scrambling sequence to data in the form of m-tuples which are to be mapped into QAM symbols. Pet. 22 (citing Ex. 1012, 12:20–28). Petitioner contends that the QAM symbols are then provided to a modulator which implements the particular signal modulation. Pet. 22; Ex. 1012, 12:55–57, Fig. 5; Ex. 1009, 41–45).

Petitioner explains, with supporting evidence, that it would have been understood by a person having ordinary skill in the art that modulating the phase-scrambled QAM symbols results in the phases of the carrier signals being scrambled. Pet. 22 (citing Ex. 1009, 44–45). Petitioner contends that it would have been obvious to a person having ordinary skill in the art to employ Stopler's phase scrambling techniques in Shively's transmitter. Pet. 22–23 (citing Ex. 1009, 45). In particular, Dr. Tellado testifies that a person having ordinary skill in the art would have recognized that by transmitting redundant data symbols on multiple carriers, Shively's transmitter would suffer from an increased peak-to-average power ratio (PAR). Ex. 1009 ¶¶ 63–64. He further testifies that a person having ordinary skill in the art would have understood the drawbacks from a high PAR and that such a person would have sought out an approach to reduce PAR of Shively's transmitter. *Id.* ¶ 66. Dr. Tellado further testifies that it would have been

obvious to randomize the carrier phases using Stopler's techniques in order to reduce Shively's PAR. *Id.* ¶ 67. Notwithstanding Patent Owner's arguments, which we have considered and which we address below, we are persuaded by Petitioner's showing, which we adopt as our own findings and conclusions, that Stopler teaches "scrambling the phase characteristics of the carrier signals" and that it would have been obvious to combine Stopler's scrambling technique to Shively's system for the reasons provided by Petitioner. Pet. 23.

Claim 1 also recites "transmitting the plurality of data bits from the first transceiver to the second transceiver." As discussed above, Petitioner relies on Shively's description of a transmitting modem (e.g., Figure 2 transmitting modem 31) that transmits digital data to a receiving modem (e.g., Figure 2 receiving modem 32). Pet. 23 (citing Ex. 1011, 8:56–60). We find that Shively describes transmitting digital data from a first transceiver to a second transceiver. Ex. 1011, 8:56–60. Petitioner further explains, with supporting evidence, and we agree, that a person having ordinary skill in the art would have understood that Shively's digital data are "data bits." Pet. 23 (citing Ex. 1009, 46); *see also* Ex. 1011, 5:47–58.

Claim 1 also recites "associating a carrier signal with a value determined independently of any bit of the plurality of data bits carried by the carrier signal, the value associated with the carrier signal determined by a pseudo-random number generator." Petitioner relies on Stopler to meet this limitation. In particular, Petitioner contends that Stopler teaches a pseudo-random generator that outputs consecutive output pairs that are converted into numbers 2a+b. Pet. 24 (citing Ex. 1012, 12:28–45). The value (2a+b), derived from the pseudo-random number generator, Petitioner

contends, is a "value determined independently of any bit of the plurality of data bits carried by the carrier signal." Pet. 24 (citing Ex. 1009, 48). Petitioner further explains, with supporting evidence, that because Stopler teaches that the value (2a+b) is associated with a symbol that is transmitted on a sub-channel having a carrier frequency, the value (2a+b) is associated with a carrier signal. Pet 24–25 (citing Ex. 1009, 48–49). We are persuaded by Petitioner's showing, which we adopt, that Stopler renders obvious associating a carrier signal with a "value determined independently of any bit of the plurality of data bits carried by the carrier signal, the value associated with the carrier signal determined by a pseudo-random number generator."

Claim 1 recites "determining a phase shift for the carrier signal at least based on the value associated with the carrier signal." Petitioner contends that Stopler teaches that the (2a+b) value is used to determine a phase shift because the sum (2a+b) is used to select the amount of rotation to be applied to the symbol, where the phase rotation can be 0, $\pi/2$, π, or $-\pi/2$. Pet. 25 (citing Ex. 1012, 12:28–45; Ex. 1009, 49). Petitioner contends that a person having ordinary skill in the art would have understood that applying a rotation to the symbol results in a phase shift in the carrier signal after the symbol is modulated onto the carrier. Pet. 25–26 (citing Ex. 1009, 49). We are persuaded by Petitioner's showing, which we adopt, that Stopler renders obvious "determining a phase shift for the carrier signal at least based on the value associated with the carrier signal."

Claim 1 recites "modulating at least one bit of the plurality of data bits on the carrier signal" and "modulating the at least one bit on a second carrier signal of the plurality of carrier signals." Petitioner points to descriptions in

Shively that describes determining "a respective carrier modulated to transmit one bit in each of a plurality of multitone subchannels of the channel" and "modulating a first set of respective carriers to represent respective unique portions of the data stream." Pet. 26 (quoting Ex. 1011, 8:3–6, 8:5–13). Petitioner further contends that Shively employs QAM multitone modulation to modulate carriers, and Shively's multiple sub-bands or QAM channels correspond to the claimed "plurality of carrier signals." Pet. 26 (citing Ex. 1009, 51). Petitioner submits that Stopler also teaches using QAM to convey data bits on carrier signals. Pet. 26–27. Petitioner further argues that Shively discloses modulating a portion of data on multiple carriers, and, therefore, meets the "second carrier" claim limitation. *Id.* at 27–29. We are persuaded by Petitioner's showing, which we adopt, that the combined teachings of Shively and Stopler render obvious "modulating at least one bit of the plurality of data bits on the carrier signal" and "modulating the at least one bit on a second carrier signal of the plurality of carrier signals."

Independent claim 15 is similar to claim 1. Petitioner has made a showing with respect to claim 15 similar to its showing with respect to claim 1. *See, e.g.*, Pet. 30–32. To the extent that claim 15 is different from claim 1, Petitioner has accounted for such differences. We also have reviewed Petitioner's showing with respect to dependent claims 2, 4, 16, and 18. Claim 2 depends from claim 1 and recites "wherein one or more of the first transceiver and second transceiver are cable transceivers." Claim 16, which depends from claim 15 is similar. Petitioner sufficiently accounts for this limitation by explaining that Stopler describes a cable modem attached to a cable television network and is a "cable transceiver." Pet. 29 (citing Ex.

1012, 1:28–33, 2:9–22, and 12:55–57; Ex. 1009, 55–56). We find that Stopler describes a cable modem that meets the limitation of a cable transceiver. Petitioner contends, and we agree, that it would have been obvious to a person having ordinary skill in the art that the data transmission techniques of Shively and Stopler could be employed with a cable transceiver. Pet. 29 (citing Ex. 1009, 56).

Claim 4 depends from claim 1 and "wherein the first and second transceivers are multicarrier DSL transceivers." Claim 18, which depends from claim 15 is similar. Petitioner sufficiently accounts for this limitation by explaining, for example, that Shively describes discrete multitoned transmission (DMT) of data by digital subscriber loop (DSL) modems. Pet. 30 (citing Ex. 1011, 1:5–8). Patent Owner does not make any additional arguments regarding claims 2, 4, 15, 16, and 18 that do not pertain to claim 1. Notwithstanding Patent Owner's arguments, which we have considered and which we address below, we are persuaded by Petitioner's showing, which we adopt as our own findings and conclusions, that claims 1, 2, 4, 15, 16, and 18 are unpatentable as obvious over Shively and Stopler.

Patent Owner's Contentions

Patent Owner argues that the combined teachings of Shively and Stopler do not render obvious the challenged claims. PO Resp. 44. In particular, Patent Owner argues that (1) Petitioner provides no explanation for the "use of a known technique to improve a similar device" rationale to combine Shively and Stopler (*id*. at 45–47); (2) Petitioner wrongly claims that Shively's transmitter suffers from an increased PAR (*id*. at 47–49); (3) Petitioner's combination of Shively and Stopler suffers from hindsight (*id*. at 49–50); (4) there is no need to solve Shively's non-existent PAR problem

(*id*. at 50–51); (5) Stopler does not reduce PAR in a multicarrier transmitter (*id*. at 51); (6) Stopler and Shively could not be combined (*id*. at 51–55); and (7) there were no "market forces" in effect to prompt the Shively/Stopler combination (*id*. at 55–57). Patent Owner also argues that Stopler does not disclose phase scrambling. *Id*. at 57–59. We address each argument below.[8]

Scrambling the Phase Characteristics of the Carrier Signals

Patent Owner argues that Stopler does not disclose "scrambling the phase characteristics of the carrier signals" required by claim 1. PO Resp. 34–44, 57–58. We note, independent claim 15 does not recite this phrase. In essence, Patent Owner argues that claim 1 requires adjusting the phases of a plurality of carriers in a single multicarrier symbol, but that Stopler only discloses scrambling phases from one symbol to the next symbol and not with respect to multiple carriers in a single multicarrier symbol. *Id*.

[8] Patent Owner lists several portions of Petitioner's Reply and evidence allegedly beyond the scope of what can be considered appropriate for a reply. *See* Paper 25. We have considered Patent Owner's listing, but disagree that the cited portions of Petitioner's Reply and reply evidence are beyond the scope of what is appropriate for a reply. Replies are a vehicle for responding to arguments raised in a corresponding patent owner response. Petitioner's arguments and evidence that Patent Owner objects to (Paper 25, 1–2) are not beyond the proper scope of a reply because we find that they fairly respond to Patent Owner's arguments raised in Patent Owner's Response. *See Idemitsu Kosan Co. v. SFC Co. Ltd.*, 870 F.3d 1376, 1381 (Fed. Cir. 2017) ("This back-and-forth shows that what Idemitsu characterizes as an argument raised 'too late' is simply the by-product of one party necessarily getting the last word. If anything, Idemitsu is the party that first raised this issue, by arguing—at least implicitly—that Arkane teaches away from non-energy-gap combinations. SFC simply countered, as it was entitled to do.").

In particular, Patent Owner contends that "Stopler must be compatible with single-carrier CDMA" (PO Resp. 58) based on Stopler's teaching that "[t]he framing scheme according to the present invention may also be performed in a CDMA system, in which case the modulator (not shown) may, for example, be a CDMA-type modulator in accordance with the TIA/EIA/IS-95 Mobile Station Compatibility Standard for Dual Mode Wideband Spread Spectrum Cellular System." Ex. 1012, 12:58–63; *see also* PO Resp. 29–30; *id.* at 29–44 (arguing Stopler's framing scheme must be compatible with single-carrier CDMA). According to Patent Owner, "[b]ecause Stopler must be compatible with single-carrier CDMA, it makes no sense to argue that his phase scrambling must be performed within a single multicarrier symbol." PO Resp. 58. Thus, concludes Patent Owner, "Stopler only discloses scrambling phases from one symbol[9] to the next symbol in time, and not with respect to multiple carriers in a single multicarrier symbol." PO Resp. 58; *see also id.* at 37 ("It is nonsensical to scramble phases within a symbol because there is only one phase in each symbol.").

Patent Owner also relies on Stopler's claim 31 as corroboration for its position, contending that the phase scrambling performed by QAM Mapper and Phase Scrambler 82 "must at least be compatible with single carrier CDMA" because claim 31 is directed to a method in a "CDMA system" that includes the step of "phase scrambling." *Id*. at 33–34 (citing Ex. 1012, 16:4–48).

[9] Patent Owner uses "symbol" to mean "a collective multicarrier symbol in a single symbol period (*e.g*. a DMT symbol)." PO Resp. 12. Patent Owner uses "carrier" to mean "a carrier symbol (*e.g*., a QAM symbol)." *Id*.

The "framing scheme" of Stopler is shown as a block diagram in Figure 5, reproduced below. Ex. 1012, 8:54–55 ("A block diagram of the framing scheme according to the present invention is shown in FIG. 5.").

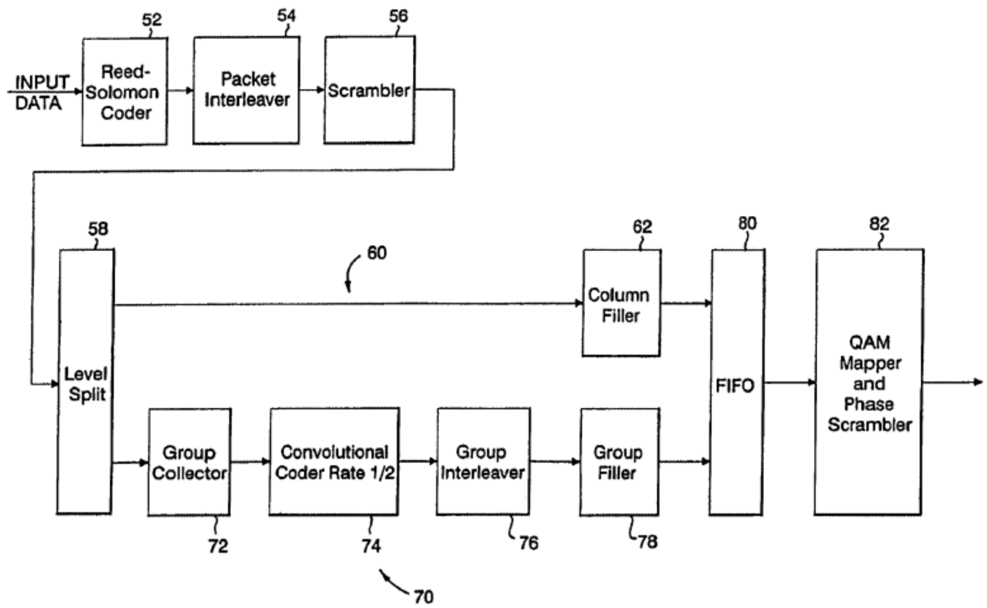
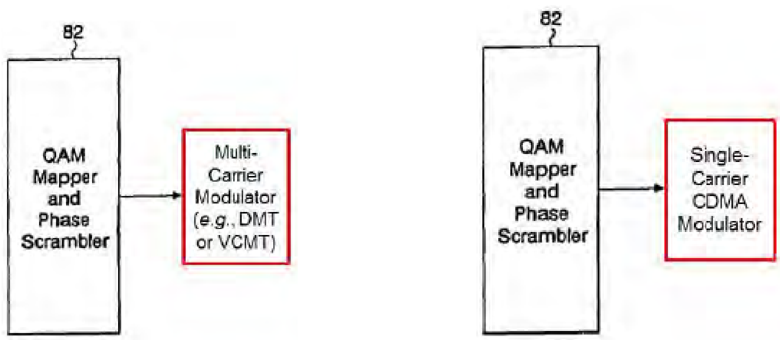


FIG. 5

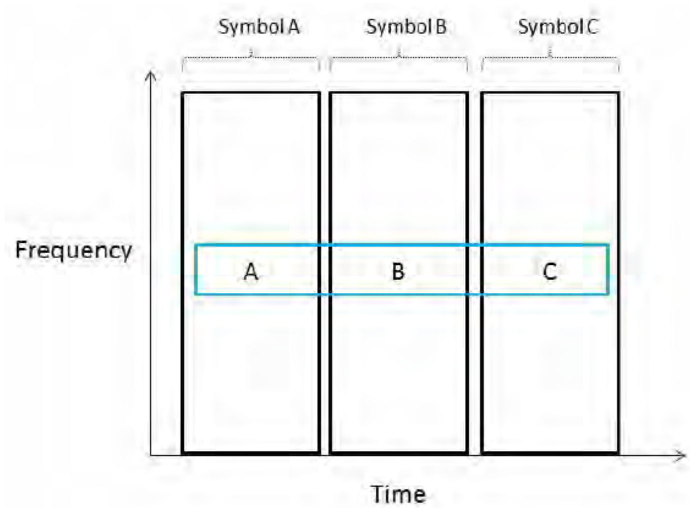
To illustrate the use of Stopler's framing scheme with either a multicarrier modulator or a single carrier modulator, Patent Owner provides the following annotated excerpts of Figure 5:



PO Resp. 33.

We are not persuaded by Patent Owner's argument, which is based upon its assertion that "[s]ingle-carrier systems have only one carrier with only one phase" and, therefore, "[p]hase scrambling in a single-carrier

system only makes sense when it is performed over time from symbol-to-symbol, as illustrated by the blue box," in the figure reproduced below. PO Resp. 36–37.



Id. In this diagram, "Symbol A," "Symbol B," and "Symbol C" each represent a QAM symbol, not a DMT symbol, and each, according to Patent Owner, is phase scrambled relative to the other. Thus, Patent Owner's diagram shows only that a single-carrier embodiment of Stopler would transmit one phase-scrambled QAM symbol at a time. It does *not* show that QAM Mapper and Phase Scrambler 82 phase scrambles a DMT symbol—i.e., rotates, by the same amount, the phase of a plurality of QAM symbols. This is consistent with the cross-examination testimony of Patent Owner's expert, Dr. Short, who admitted that Stopler does not describe phase scrambling DMT symbols. Pet. Reply 17–18 (citing Ex. 1027, 60:11–14). Thus, Patent Owner's own diagram is consistent with Petitioner's position that Stopler phase scrambles individual QAM symbols, and Patent Owner identifies nothing in Stopler to suggest that, in an alternative embodiment with a multicarrier modulator, QAM Mapper and Phase Scrambler 82 do not

supply a plurality of phase-scrambled QAM symbols for modulation onto the plurality of carriers in the, e.g., DMT symbol.

Whereas Patent Owner's position relies upon inference, Petitioner's position is supported by express disclosure in Stopler, which unambiguously teaches "QAM symbols, for example,[] 256-QAM" whose "constellation mapping may be the same as that used in ADSL." Ex. 1012, 12:20–24. Stopler further teaches that, "a phase scrambling sequence is applied to the output symbols," including "all symbols, not just the overhead symbols." *Id.* at 12:25–28. Patent Owner's expert, Dr. Short, agreed that Stopler is referring to phase scrambling QAM symbols. Pet. Reply 16–17 (citing Ex. 1027, 54:17–55:3, 55:19–24, 58:6–8, 59:9–12, and 60:15–22). Stopler further teaches that a "scrambling sequence may be generated by a pseudo-random generator" that generates pairs whose sum "is used to select the amount of rotation to be applied to the symbol," singular; not "symbols" plural. Ex. 1012, 12:28–36. Thus, the most intuitive reading of Stopler supports Petitioner's contention that QAM Mapper and Phase Scrambler 82 determines an amount of rotation and rotates the phase of a *single* QAM symbol by that amount. Patent Owner, in contrast, identifies nothing in Stopler to suggest that QAM Mapper and Phase Scrambler 82 rotates the phase of a *plurality* of QAM symbols (e.g., every QAM symbol of a DMT symbol) by the same amount. Finally, we agree with Petitioner's argument that because "a CDMA modulator does not employ DMT symbols, there is no reason for Stopler's phase scrambler to operate on DMT symbols," whereas "both DMT and CDMA modulators employ QAM symbols," so "applying the phase scrambler to individual QAM symbols[] is the only

possible reading that is logically and technically coherent." Pet. Reply 18 (citing Ex. 1026 ¶ 58).

Patent Owner also argues that a person of ordinary skill in the art would have understood Stopler to be scrambling phase from symbol-to-symbol over time in order to reduce narrowband noise at the frequency of an overhead pilot carrier. PO Resp. 39; *see also id.* at 38–44 (citing Ex. 2004 (U.S. Patent 6,370,156, "the '156 patent")). According to Patent Owner, "Petitioners' argument that Stopler discloses phase scrambling within one symbol is based on the premise that the symbol can have multiple pilot tones." *Id.* at 40. We understand Patent Owner to be alluding to pages 13 to 14 of the Petition, which state

> Stopler also explains that some of the available carriers may be reserved for the transmission of overhead signals, such as pilot tones. Ex. 1012, 10:60-62 & 12:51-54. To randomize these overhead channels, Stopler employs a phase scrambler. Ex. 1012, 12:24-26.

Pet. 13. In the claim-by-claim analysis of the Petition, however, Petitioner cites lines 20 to 28 of column 12, which include Stopler's teaching that "the phase scrambler is applied to all symbols, not just the overhead symbols." *See* Pet. 22 (quoting Ex. 1012, 12:27–28). Thus, Petitioner is relying not just on the scrambling of "overhead signals, such as pilot tones," (Pet. 13) but on the scrambling of *all* QAM symbols. Because neither Petitioner's argument nor Stopler's teaching of phase scrambling is limited to pilot tones, Patent Owner's argument is not persuasive.

Finally, we are not persuaded by Patent Owner's argument that only its interpretation—i.e., adjusting the phase of an entire DMT symbol—would "simplify implementation," as Stopler teaches (Ex. 1012, 12:26),

whereas Petitioner's interpretation would add complexity. PO Resp. 44 (citing Ex. 2003 ¶ 90). Patent Owner provides no explanation or analysis to support its conclusory assertions regarding simplicity and complexity, and the cited portion of Dr. Short's declaration merely repeats what is written in the Patent Owner's Response.

For the foregoing reasons, we are persuaded that Stopler teaches "scrambling the phase characteristics of the carrier signals" required by claim 1.

No Use of a Known Technique to Improve a Similar Device Rationale

Patent Owner argues that in making the contention that the combination of Shively and Stopler is a use of a known technique to improve a similar device, method or product in the same way, Petitioner fails to explain what is the known technique, what device/method/product is similar, and how is the alleged known technique used for improvement in the same way. PO Resp. 45–47.

In the Petition, Petitioner provides sufficient explanation regarding the reasons to combine Shively and Stopler. Pet. 14–16. The explanation provided in the Petition is not conclusory or confusing as Patent Owner asserts. The known technique is identified as phase scrambling. Pet. 15 (citing Ex. 1009, 29). The similar device is Shively's modem. Pet. 17. And the improvement to it is the same as in Stopler—to reduce PAR. Pet. 16 (citing Ex. 1009, 29).

Shively's transmitter does not suffer from an increased PAR and there is no reason to solve Shively's non-existent PAR problem

Patent Owner argues that "Shively does not suffer from an increased PAR, much less one that would be recognized as a problem. Rather,

Shively's disclosed embodiment results in a substantially reduced PAR (and one that is very far below a level that is problematic)." PO Resp. 47–49. Patent Owner also argues that because Shively does not disclose a problem with PAR, one having ordinary skill in the art would have had no reason to look for a solution. PO Resp. 50–51. We are not persuaded by these arguments.

Specifically, Patent Owner argues Shively's system is unlikely to suffer from clipping,[10] based on its analysis of a hypothetical 18,000 foot wire. PO Resp. 19–29. According to Patent Owner, the power of signals transmitted in Shively's proposed system would be "only 40% of maximum" in the normal mode for ADSL-1995 and "only 49% of maximum" in the power-boost mode of ADSL-1995. *Id.* Based on these figures, Patent Owner concludes that "the clipping probability for both normal and power-boost modes is virtually zero" because "[w]hile Shively's 'spreading' technique will contribute a small uptick in clipping probability, any increase would be negated by the enormous reduction in clipping probability achieved by reducing signal power by more than half." *Id.* at 28.

Petitioner argues that Dr. Short's analysis is flawed because (1) the teachings of Shively are not applicable only to 18,000 foot cables; and (2) Dr. Short "grossly underestimates the likelihood of phase alignment" in Shively because he wrongly assumes a Gaussian distribution. Pet. Reply 26–31. According to Petitioner, a proper analysis shows that Shively's

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[10] Patent Owner explains that, "[w]hen the maximum dynamic range of a component is exceeded, the signal will become distorted or will 'clip.'" PO Resp. 8. This is consistent with how the '158 patent uses "clipping." *See, e.g.,* Ex. 1001, 8:27–35.

techniques "significantly increases PAR and the likelihood of clipping." Pet. Reply 31–35.

We need not determine the exact probability of clipping in Shively's proposed system because, even assuming Patent Owner's analysis is accurate, it does not rebut Petitioner's reason to combine. Petitioner does not allege that Shively's proposed system causes clipping, or that a person of ordinary skill in the art would have been motivated to reduce PAR only if it caused clipping. Instead, Petitioner alleges that Shively's proposed system would have an "increased" or "high" PAR:

> A POSITA would have recognized that by transmitting redundant data on multiple carriers, *Shively's transmitter would suffer from an increased peak-to-average power ratio*. [Ex. 1009, p. 27.] This increase is due to the fact that the overall transmitted signal in a multicarrier system is essentially the sum of its multiple subcarriers. *Id*. When *N* subcarrier signals with the same phase are added together, they have a peak power which is *N* times greater than their individual maximum powers. *Id*.
>
> Since Shively's subcarriers use quadrature amplitude modulation (QAM) . . . transmitting the same bits on two different subcarriers causes those subcarriers to have the same phase and amplitude. *Id*., pp. 27–28. By transmitting the same bits on multiple subcarriers, Shively creates a situation where those multiple subcarriers will be phase-aligned. *Having phase-aligned subcarriers causes a high peak-to-average power ratio (PAR), since all of the subcarriers add up coherently at the same time*. *Id*., p. 28.

Pet. 14–15 (emphases added).

Patent Owner criticizes Petitioner's declarant for not providing "calculations or data that illustrate to what degree there is an 'increase' in PAR with Shively's transmitter" (PO Resp. 48), but we are not persuaded

that such calculations and data are necessary. Petitioner's reason to combine does not depend on the PAR increase exceeding some specific numeric threshold. There is no dispute that transmitting the same data on multiple carriers increases PAR (Pet. Reply 10 (citing PO Resp. 6–7; Ex. 2003 (Short Decl.) ¶ 22)) or that Shively's technique, specifically, will increase PAR (PO Resp. 28 ("Shively's 'spreading' technique will contribute a small uptick in clipping probability."). There also is no dispute that equipment designed to handle a higher PAR can be larger, more expensive, and more power hungry than equipment designed to handle a lower PAR. Pet. Reply 36 (citing Ex. 2003 ¶ 26; Ex. 1027 45:21–46:19). Patent Owner's declarant, Dr. Short, testified that, given such issues, system designers or engineers would be interested in using techniques that could reduce PAR. Ex. 1027, 46:23–47:3. This is consistent with the reason to combine given in the Petition and supports Petitioner's position that "numerous problems" other than clipping "would have motivated a [person of ordinary skill in the art] to look for ways to reduce the PAR of Shively's technique." Pet. Reply 36.

In light of the foregoing, we are persuaded that a person of ordinary skill in the art would have recognized that Shively's technique would increase PAR and would have been motivated to reduce PAR regardless of whether Shively's technique resulted in clipping.

Combination of Shively and Stopler suffers from hindsight

Patent Owner argues that only the inventor of the '158 patent recognized the problem of high PAR due to phase-aligned carriers. PO Resp. 49–50. Patent Owner argues that the only cited evidence that high PAR results from transmitting the same data on multiple carriers is from the '158 patent and that Petitioner "use[s] the '158 patent as a roadmap for

arriving at their theory of obviousness," resulting in "a textbook case of impermissible hindsight bias." *Id*. We are not persuaded by this argument.

First, the portions cited in the '158 patent in the Petition and in Dr. Tellado's declaration come from the "BACKGROUND OF THE INVENTION" section of the patent. That portion of the '158 patent uses words such as "conventional" indicating that what is described in the "BACKGROUND OF THE INVENTION" section is information that was known at the time of the invention, not just by the inventors, but persons of ordinary skill in the art. Patent Owner does not contend otherwise.

In addition, Dr. Tellado testified that a person having ordinary skill in the art would have recognized that the purpose of Stopler's phase scrambler to randomize data symbols would be to reduce PAR of transmitted signals and that the person would have been familiar with the problems created by a high PAR, including PAR due to phase-aligned carriers. Ex. 1009 ¶¶ 60, 66. Moreover, Patent Owner's own declarant recognized that PAR was a known problem at the time of the invention. Ex. 2003 ¶ 23 ("Conventional multicarrier systems, therefore, were designed to accommodate PAR."). The ANSI T1.413-1995 standard also confirms that PAR was known at the time of the invention by describing that "[a] DMT time-domain signal has a high peak-to-average ratio (its amplitude distribution is almost Gaussian), and large values may be clipped by the digital-to-analog converter." Ex. 1018, 36 (Section 6.5 "Tone ordering"). Based on the record evidence, we find that a person having ordinary skill in the art would have known about the problem of high PAR due to phase-aligned carriers.

Stopler does not reduce PAR in a multicarrier transmitter

Patent Owner argues that Stopler does not reduce PAR because phase scrambling is performed from symbol-to-symbol and not from carrier-to-carrier. PO Resp. 51. The argument is not persuasive for the reasons provided above.

Stopler and Shively could not be combined

Patent Owner argues that Shively and Stopler are incompatible and that it would not have been possible to incorporate Shively's bit-spreading concept into Stopler. PO Resp. 51. In particular, Patent Owner argues that Shively's bit-spreading concept is not compatible with Stopler's "diagonalization" technique. PO Resp. 51–55. This argument is misplaced as Petitioner did not rely on Stopler's "diagonalization" technique. Rather, Petitioner relies on Stopler's phase scrambler and scrambling technique. Pet. 15, 22–23. Moreover, Stopler describes its "diagonalization" technique as optional. Ex. 1012, 10:17, 13:1–3. For these reasons, we are not persuaded by Patent Owner's argument that it would not be possible to combine Shively and Stopler.

No "market forces" in effect to prompt Shively/Stopler combination

The Petition states that "[m]arket forces would have prompted the development of multicarrier communications devices, such as Digital Subscriber Line (DSL) modems, employing both redundant bit transmission and phase scrambling." Pet. 16 (citing Ex. 1009, 29). Patent Owner argues that neither Petitioner nor Dr. Tellado identifies a single product or standard that employs any of the ideas disclosed in Shively or Stopler. PO Resp. 55–57.

Patent Owner's arguments are misplaced. It was not incumbent on Petitioner or Dr. Tellado to identify a product or standard that employs the ideas disclosed in Shively or Stopler in order to show that the combination of Shively and Stopler would have been obvious to a person skilled in the art. That is not the standard. Rather, a claim is unpatentable under 35 U.S.C. § 103(a) if the differences between the claimed subject matter and the prior art are such that the subject matter, as a whole, would have been obvious at the time of the invention to a person having ordinary skill in the art. *KSR*, 550 U.S. at 406. Dr. Tellado testified that a person having ordinary skill in the art would have been familiar with problems caused by a high PAR, that equipment needed to cope with PAR would have been expensive and inefficient, and that less capable equipment would have caused distortion such as from amplitude clipping. Ex. 1009 ¶ 66. He further testified that combining Shively's redundant bit transmission with Stopler's phase scrambling technique would have allowed for faster DSL modems without requiring more complex and expensive circuitry for handling increased PAR. *Id.* ¶ 69. Patent Owner has not presented sufficient evidence to undermine Dr. Tellado's testimony. Indeed, Dr. Short testified that a way to address high PAR in a communication system would be to use transceiver components that could handle higher peak transmission values, which would be expensive and power hungry. Ex. 1027, 45:15–46:12. Based on the record before us, we find that at the time of the invention, a person having ordinary skill in the art would have recognized that an increase in PAR would have been associated with more expensive communication equipment. Accordingly, a drive to reduce equipment costs would have motivated a person having ordinary skill in the art to include

Stopler's phase scrambler into Shively's transmitter to reduce PAR. Pet. 14–16 (citing Ex. 1009 ¶¶ 66–70).

For the foregoing reasons, we are persuaded that Petitioner has established, by a preponderance of the evidence, that claims 1, 2, 4, 15, 16, and 18 of the '158 patent are unpatentable under 35 U.S.C. § 103(a) as obvious over Shively and Stopler.

E. Asserted Obviousness over Shively, Stopler, and Gerszberg

Petitioner contends that claims 3, 5, 14, 17, 19, and 28–30 are unpatentable under 35 U.S.C. § 103(a) as obvious over Shively, Stopler, and Gerszberg. Pet. 33–41. Relying on the testimony of Dr. Jose Tellado, Petitioner explains how the combination of Shively, Stopler, and Gerszberg meets all of the claim limitations. *Id.* (citing Ex. 1009).

Gerszberg discloses using a Digital Subscriber Line (DSL) modem, such as an ADSL modem, to transmit and receive modulated data. Ex. 1013, 11:66–12:7. The modem uses DMT modulation to transmit data. *Id.* at 12:7–9. Gerszberg further describes types of data services that may be provided to subscriber premises by a DSL modem that uses DMT modulation, such as high-speed internet access and video services. *Id.* at 7:44–60, 8:16–36, and 10:63–11:3. Gerszberg also describes that a DSL modem can be used in various DSL communications, such as HDSL, ADSL, SDSL, and VDSL. *Id.* at 9:66–10:3.

Based on the record before us, Petitioner has accounted sufficiently for dependent claims 3, 5, 14, 17, 19, and 28–30. Pet. 33–41. For example, claim 3 depends from claim 1 and recites "wherein one or more of the first transceiver and second transceiver are VDSL transceivers." Claim 17, which depends from independent claim 15, is similar to claim 3. Petitioner

relies on Gerszberg's description that its "DSL modem may be constructed using any of the techniques described in the applications incorporated by reference below" such as "High Speed Digital Subscriber Line (HDSL), Asymmetric Digital Subscriber Line (ADSL), Symmetrical Digital Subscriber Line (SDSL) and Very high data rate Digital Subscriber Line (VDSL)." Pet. 37–38 (citing Ex. 1013, 9:62–10:3) (emphasis omitted). Petitioner contends that it would have been obvious to replace Shively's ADSL modems with VDSL modems, as taught by Gerszberg, in order to achieve higher bandwidth. Pet. 38 (citing Ex. 1009, 67). Moreover, Petitioner provides a rational reason for combining Gerszberg with the combined teachings of Shively and Stopler. Pet. 34–37. Patent Owner does not present arguments for any of those claims separate from the arguments addressed previously.

We are persuaded by Petitioner's showing, which we adopt as our own findings and conclusions, that claims 3, 5, 14, 17, 19, and 28–30 are unpatentable as obvious over Shively, Stopler, and Gerszberg.

F. Asserted Obviousness over Shively, Stopler, and Bremer

Petitioner contends that claims 6, 9, 10, 12, 20, 23, 24, and 26 are unpatentable under 35 U.S.C. § 103(a) as obvious over Shively, Stopler, and Bremer. Pet. 41–50. Relying on the testimony of Dr. Jose Tellado, Petitioner explains how the combination of Shively, Stopler, and Bremer allegedly meets all of the claim limitations. *Id*. (citing Ex. 1009).

Bremer relates to encoding and decoding techniques for a data signal that is transmitted over a communications channel. Ex. 1017, 1:41–67. Bremer describes using a pseudorandom generator to encode the gain or phase of a signal prior to transmission, and on the receiving end, uses a

second pseudorandom generator to decode the encoded data signal. *Id*. at 1:53–64.

Based on the record before us, Petitioner has accounted sufficiently for dependent claims 6, 9, 10, 12, 20, 23, 24, and 26. Pet. 41–50. For example, claim 6 depends from claim 1 and recites "independently deriving the values associated with each carrier using a second pseudo-random number generator in the second transceiver." Claim 20, which depends from independent claim 15, is similar to claim 6. Petitioner contends that Bremer teaches that when a transmitting device includes components causing a pseudorandom phase shift to the transmitted signal, a receiving device requires complementary components to decode the signal. Pet. 45 (citing Ex. 1017, 1:60–65, 4:33–34). Petitioner further contends that Bremer describes altering gain and phase modifiers of a data signal being transmitted from a QAM modem based on values from a pseudorandom signal generator, which generates a pseudorandom number. Pet. 45 (citing Ex. 1017, Abstract, 2:32; Ex. 1009, 77). Petitioner further contends that the values produced by a second pseudorandom number generator are independent of the values produced by a first pseudorandom number generator. Pet. 46 (citing Ex. 1017, 4:10–16, 4:35–36; Ex. 1009, 80). Petitioner provides rational reasoning for combining Bremer with the combined teachings of Shively and Stopler. Pet. 42–44.

Notwithstanding Patent Owner's arguments, which we address immediately below, we are persuaded by Petitioner's showing, which we adopt as our own findings and conclusions, that claims 6, 9, 10, 12, 20, 23, 24, and 26 are unpatentable as obvious over Shively, Stopler, and Bremer.

Patent Owner's Contentions

Patent Owner argues that Petitioner fails to allege a legally sufficient rationale for combining Bremer's single-carrier privacy modem system, and for modifying it such that it would have been compatible with Shively/Stopler's multicarrier systems. PO Resp. 59–60. We are not persuaded by this argument.

As explained above, Petitioner relies on Bremer for its teaching of a second pseudo-random number generator to meet the limitations of claims 6 and 20. Patent Owner quotes the reasons provided in the Petition at pages 46–47 for combining Bremer with the Shively/Stopler combination and argues that Petitioner's allegations present more questions than answers. *Id.* at 60. Patent Owner argues that Dr. Tellado provides no additional guidance. *Id.* (citing Ex. 1009, 81). We disagree with Patent Owner that Petitioner failed to provide a sufficient rationale and reasoning for modifying the combined teachings of Shively and Stopler with Bremer.

Patent Owner's focus on one passage from the Petition and one passage from Dr. Tellado's testimony overlooks other supported contentions made by Petitioner. In particular, the Petition explains that a person having ordinary skill in the art would have understood that the transceivers and receivers described in both Stopler and Shively would have been a matched pair and that the techniques used by a transmitter to encode data for transmission would have been paralleled by techniques used by a receiver to decode data. Pet. 42–43 (citing Ex. 1009, 74; Ex. 1017, 1:60–63). The Petition further explains that a person having ordinary skill in the art would have understood that a receiver must be able to reverse the phase modification applied by a transmitter. Pet. 43 (citing Ex. 1009, 75; Ex.

1017, 1:34–36). Petitioner explains that the combination of Shively, Stopler, and Bremer would have been obvious to a person of ordinary skill in the art because it is the application of a known technique (designing a receiver to match a transmitter) to improve a similar system in the same way (allowing data to be received). Pet. 44 (citing Ex. 1009, 76). Moreover, Dr. Tellado testified that "[a]lthough Bremer describes a single-carrier QAM communication system, it would have been obvious to a POSITA that Bremer's teaching of a complementary pseudo-random number generator, and performing complementary changes of the received signal, could be applied on a carrier-by-carrier basis to the multicarrier system of Stopler." Ex. 1009, 81. We agree with Petitioner's reasoning and rationale provided, and determine it would have been obvious to include Bremer's second pseudo-random number generator in the combined Shively/Stopler system receiver in order to decode and receive the phase scrambled data transmitted by the system transceiver. Ex. 1009, 73–76, 81.

G. Asserted Obviousness over Shively, Stopler, Bremer, and Gerszberg

Petitioner contends that claims 8, 11, 13, 22, 25, and 27 are unpatentable under 35 U.S.C. § 103(a) as obvious over Shively, Stopler, Bremer, and Gerszberg. Pet. 50–53. Relying on the testimony of Dr. Jose Tellado, Petitioner explains how the combination of Shively, Stopler, Bremer, and Gerszberg allegedly meets all of the claim limitations. *Id.* (citing Ex. 1009).

Based on the record before us, Petitioner has accounted sufficiently for dependent claims 8, 11, 13, 22, 25, and 27. Pet. 50–53. For example, claim 11 depends from claim 6, and recites "wherein the first and second transceivers are VDSL transceivers." Claim 25, which depends from claim

20, is similar to claim 11. Petitioner relies on Gerszberg's description that its "DSL modem may be constructed using any of the techniques described in the applications incorporated by reference below" such as "High Speed Digital Subscriber Line (HDSL), Asymmetric Digital Subscriber Line (ADSL), Symmetrical Digital Subscriber Line (SDSL) and Very high data rate Digital Subscriber Line (VDSL)." Pet. 37–38 (emphasis omitted) (citing Ex. 1013, 9:62–10:3). Petitioner contends that it would have been obvious to replace Shively's ADSL modems with VDSL modems, as taught by Gerszberg, in order to achieve higher bandwidth. Pet. 38, 52 (citing Ex. 1009, 67, 89). Moreover, Petitioner provides a rational reason for combining Gerszberg with the combined teachings of Shively and Stopler. Pet. 50–51. Patent Owner does not present arguments for any of those claims separate from the arguments addressed previously.

We are persuaded by Petitioner's showing, which we adopt as our own findings and conclusions, that claims 8, 11, 13, 22, 25, and 27 are unpatentable as obvious over Shively, Stopler, Bremer, and Gerszberg.

H. Asserted Obviousness over Shively, Stopler, Bremer, and Flammer

Petitioner contends that claims 7 and 21 are unpatentable under 35 U.S.C. § 103(a) as obvious over Shively, Stopler, Bremer, and Flammer. Pet. 53–60. Relying on the testimony of Dr. Jose Tellado, Petitioner explains how the combination of Shively, Stopler, Bremer, and Flammer allegedly meets all of the claim limitations. *Id.* (citing Ex. 1009).

Flammer relates to data transmission between a source node and a target node, where each node has a transmitter and a receiver. Ex. 1019, Abstract. Flammer uses pseudo-random number generators in its communication system. Flammer describes synchronization between

pseudo-random number generators at different ends of a communication channel. *Id.* at 3:49–4:10. As part of the synchronization, an acquisition/ synchronization packet is transmitted that includes a seed value from the source node to the target node. *Id.* at 3:52–58. The transmitted seed value is used to initialize the pseudo-random number generators executing at the respective source and target nodes. *Id.* at 3:52–4:9. Once the pseudo-random number generators at both the source node and the target node have the same seed value, they can generate identical pseudo-random number sequences for selecting frequency bands. *Id.* at 4:42–53.

Based on the record before us, Petitioner has accounted sufficiently for dependent claims 7 and 21. Pet. 50–53. Claim 7 depends from claim 6 and recites "using in the first and second transceivers a same seed for the first and second pseudo-random number generators and the value of the seed is transmitted from the first transceiver to the second transceiver." Claim 21, which depends from claim 20, is similar to claim 7. Petitioner contends that Flammer teaches a transceiver as a node having a transmitter and a receiver. Pet. 57 (citing Ex. 1019, Abstract). Petitioner further contends that in Flammer, the source node is the first transceiver and the target node is the second transceiver. Ex. 1009, 92. Petitioner argues that Flammer teaches that it was known for the pseudo-random number generators in the source node and the target node to use the same seed value. Pet. 57 (citing Ex. 1019, 3:52–67; Ex. 1009, 92–93). Petitioner further explains, with supporting evidence, that Flammer teaches transmitting a value of a seed from a source node (a first transceiver) to a target node (a second transceiver) when the target node receives an acquisition/synchronization packet which contains information about the node, including a seed value.

Moreover, Petitioner provides a rational reason for combining Flammer with the combined teachings of Shively, Stopler, and Bremer. Pet. 54–57. Patent Owner does not present arguments for either of claims 7 and 21 separate from the arguments addressed previously.

We are persuaded by Petitioner's showing, which we adopt as our own findings and conclusions, that claims 7 and 21 are unpatentable as obvious over Shively, Stopler, Bremer, and Flammer.

I. Patent Owner's Motion to Exclude

Patent Owner moves to exclude Exhibits 1022–1025, 1028, and portions of 1026 and 2013. PO Mot. Exc. Exhibit 1022 is styled "Robert T. Short, 'Physical Layer,' *in* WIMEDIA UWB (2008)." Pet. Reply 5. Patent Owner argues that we should exclude Exhibit 1022 as irrelevant. PO Mot. Exc. 2–4. Exhibit 1022 was not cited or discussed in any way in Petitioner's Reply. Moreover, we did not rely on Exhibits 1022 in rendering our decision. We did not and need not consider Exhibit 1022. We have determined that Petitioner has demonstrated, by a preponderance of the evidence, that the challenged claims are unpatentable, without considering the specific objected to evidence.

Exhibit 1023 is styled "Denis J. G. Mestdagh and Paul M. P. Spruyt, 'A Method to Reduce the Probability of Clipping in DMT-Based Transceivers," *IEEE Transactions on Communications*, Vol. 44, No. 10, (October 1996)." Pet. Reply 5. Exhibit 1024 is styled "Stefan H. Muller and Johannes B. Huber, 'A Comparison of Peak Power Reduction Schemes for OFDM,' IEEE Global Telecommunications Conference (1997)." *Id.* Exhibit 1028 is styled "T. Starr, J. M. Cioffi, P. J. Silverman, UNDERSTANDING DIGITAL SUBSCRIBER LINE TECHNOLOGY (1999) (selected

pages).” *Id*. Exhibit 2013 is a copy of the cross examination transcript of Dr. Tellado.

Patent Owner argues that we should exclude Exhibits 1023, 1024, and 1028 in their entirety as irrelevant. PO Mot. Exc. 9–12. Patent Owner also argues that we should exclude certain portions of Exhibit 2013 allegedly discussing Exhibits 1023, 124, or 1028. *Id*. Although Exhibits 1023, 1024, and 1028 are mentioned briefly in Petitioner’s Reply, we did not rely on Exhibits 1023, 1024, 1028, or the objected to portions of Exhibit 2013 in rendering our decision. We did not and need not consider Exhibits 1023, 1024, 1028, or the objected to portions of Exhibit 2013. We have determined that Petitioner has demonstrated, by a preponderance of the evidence, that the challenged claims are unpatentable, without considering the specific objected to evidence.

Exhibit 1025 is a copy of Dr. Tellado’s thesis. Pet. Reply 5. Patent Owner argues that we should exclude Exhibit 1025 as irrelevant. PO Mot. Exc. 4–6. Exhibit 1025 was not cited or discussed in any way in Petitioner’s Reply. Moreover, we did not rely on Exhibits 1025 in rendering our decision. We did not and need not consider Exhibit 1025. We have determined that Petitioner has demonstrated, by a preponderance of the evidence, that the challenged claims are unpatentable, without considering the specific objected to evidence.

Lastly, Patent Owner seeks to exclude paragraphs 16 (last two sentences), 29, 42, 43 (first sentence), and 52 of Exhibit 1026 (Second Tellado Declaration), and certain portions of Dr. Tellado’s cross examination transcript (Exhibit 2013). PO Mot. Exc. 6–9. We did not rely on the objected to portions of Exhibits 1026 or 2013 in rendering our

decision. We did not and need not consider the objected to portions of Exhibits 1026 or 2013. We have determined that Petitioner has demonstrated, by a preponderance of the evidence, that the challenged claims are unpatentable, without considering the specific objected to evidence.

For all of the above reasons, we *dismiss* Patent Owner's Motion to Exclude.

J. Motion for Observations

Patent Owner also filed a Motion for Observations (Paper 30, "PO Mot. Obs."), to which Petitioner filed a Response (Paper 37, "Pet. Resp."). To the extent Patent Owner's Motion for Observations pertains to testimony purportedly impacting Dr. Tellado's credibility, we have considered Patent Owner's observations and Petitioner's responses in rendering this Final Written Decision, and accorded Dr. Tellado's testimony appropriate weight in view of Patent Owner's observations and Petitioner's response to those observations. *See* Obs. 1–13; Obs. Resp. 2–11.

III. CONCLUSION

Based on the evidence and arguments, Petitioner has demonstrated by a preponderance of the evidence that claims 1, 2, 4, 15, 16, and 18 are unpatentable over Shively and Stopler; claims 3, 5, 14, 17, 19, and 28–30 are unpatentable over Shively, Stopler, and Gerszberg; claims 6, 9, 10, 12, 20, 23, 24, and 26 are unpatentable over Shively, Stopler, and Bremer; claims 8, 11, 13, 22, 25, and 27 are unpatentable over Shively, Stopler, Bremer, and Gerszberg; and claims 7 and 21 are unpatentable over Shively, Stopler, Bremer, and Flammer.

IV. ORDER

Accordingly, it is:

ORDERED that claims 1–30 of the '158 patent have been shown to be unpatentable;

FURTHER ORDERED that Patent Owner's Motion to Exclude is *dismissed*; and

FURTHER ORDERED that, because this is a final written decision, parties to the proceeding seeking judicial review of the decision must comply with the notice and service requirements of 37 C.F.R. § 90.2.

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Paper No. 46
Entered: February 1, 2018

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CISCO SYSTEMS, INC., DISH NETWORK, LLC,
COMCAST CABLE COMMUNICATIONS, LLC,
COX COMMUNICATIONS, INC.,
TIME WARNER CABLE ENTERPRISES LLC,
VERIZON SERVICES CORP., and ARRIS GROUP, INC.,
Petitioner,

v.

TQ DELTA, LLC,
Patent Owner.

Case IPR2016-01021[1]
Patent 8,718,158 B2

Before SALLY C. MEDLEY, TREVOR M. JEFFERSON, and
MATTHEW R. CLEMENTS, *Administrative Patent Judges*.

MEDLEY, *Administrative Patent Judge*.

DECISION
Denying Patent Owner's Rehearing Request
37 C.F.R. § 42.71

[1] DISH Network, L.L.C., who filed a Petition in IPR2017-00255, and Comcast Cable Communications, L.L.C., Cox Communications, Inc., Time Warner Cable Enterprises L.L.C., Verizon Services Corp., and ARRIS Group, Inc., who filed a Petition in IPR2017-00417, have been joined in this proceeding.

I. INTRODUCTION

Pursuant to 37 C.F.R. § 42.71(d), TQ Delta, LLC ("Patent Owner") requests rehearing of our Final Written Decision (Paper 44, "Dec."). Paper 45 ("Req. Reh'g"). Specifically, Patent Owner submits that our construction of "scrambling the phase characteristics of the carrier signals" misapprehends or overlooks certain evidence, that Stopler[2] does not disclose "scrambling the phase characteristics of the carrier signals," that we misapprehended or overlooked certain testimony, and that we misapprehended that Shively[3] would not have an increased or high PAR. Req. Reh'g *passim*.

For the reasons set forth below, Patent Owner's Request for Rehearing is *denied*.

II. STANDARD OF REVIEW

A party requesting rehearing bears the burden of showing that the decision should be modified. 37 C.F.R. § 42.71(d). The party must identify specifically all matters we misapprehended or overlooked, and the place where each matter was addressed previously in a motion, an opposition, or a reply. *Id.* With this in mind, we address the arguments presented by Patent Owner.

III. ANALYSIS

A. "scrambling the phase characteristics of the carrier signals"

Claim 1 recites "a method for scrambling the phase characteristics of the carrier signals, comprising." We adopted Patent Owner's proposed

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[2] U.S. Patent No. 6,625,219 B1; issued Sept. 23, 2003 (Ex. 1012) ("Stopler").
[3] U.S. Patent No. 6,144,696; issued Nov. 7, 2000 (Ex. 1011) ("Shively").

construction in part by construing "scrambling the phase characteristics of the carrier signals" to mean "adjusting the phases of a plurality of carriers in a single multicarrier symbol." Dec. 8–11. We did not add to that construction "by pseudo-randomly varying amounts" because Patent Owner did not show why that additional language should be included for the broadest reasonable construction of the term "scrambling the phase characteristics of the carrier signals." *Id*. Patent Owner argues that our construction is overly broad because it encompasses adjusting the phases of every carrier in the single multicarrier symbol by the same amount. Req. Reh'g. 2–3. Such an adjustment, according to Patent Owner, would not reduce peak-to-average power ratio ("PAR"), which the parties and the panel all agree scrambling must do. *Id.* at 3–6. "The FWD misapprehends or overlooks that, under any proper construction, there must at a minimum be *varying amounts* by which the phases are adjusted within a single multicarrier symbol (*i.e.*, *from carrier-to-carrier*) such that PAR is reduced." *Id.* at 2.

Patent Owner presents arguments not presented previously. We could not have overlooked or misapprehended those arguments presented for the first time in the rehearing request. Importantly, Patent Owner argues now for the first time that for any proper construction "there must at a minimum be varying amounts by which the phases are adjusted within a single multicarrier symbol (i.e., from carrier-to-carrier) such that PAR is reduced." *Id.* at 2. This proposed construction differs from Patent Owner's original proposed construction which included "by pseudo-randomly varying amounts." Absent from the new proposed construction is the term "pseudo-randomly."

In any event, it is clear from the Decision that we construed the totality of claim 1, for example, as requiring varying the amount by which the phase of each carrier is adjusted. *See, e.g.*, Dec. 28. Accordingly, even if we were to adopt Patent Owner's new proposed construction, it would not change the way we applied the prior art to the claim language as a whole.

B. Stopler's Single-Carrier Embodiment

Patent Owner argues that Stopler's QAM Mapper and Phase Scrambler 82 "must be compatible with single-carrier CDMA" because Stopler teaches that its output can, in one embodiment, be provided to a CDMA modulator. Req. Reh'g. 7–8. Patent Owner concludes that Stopler's phase scrambling "must have a different purpose than the claimed phase scrambling because [it] . . . cannot reduce PAR." *Id.* at 8.

We addressed this argument and found it unpersuasive. Dec. 23–28. Mere disagreement with the Board's conclusion is not a proper basis for rehearing. It is not an abuse of discretion to have made a conclusion with which a party disagrees.

C. Allegedly Misapprehended or Overlooked Testimony

Patent Owner quotes pages 25 to 26 of our Decision and argues that "there are several inaccuracies." Req. Reh'g 8–12. These arguments are based, in part, on a mischaracterization of our claim construction as *requiring* the same amount of rotation of the phase of each of the QAM symbols in a DMT symbol. *See, e.g., id.* at 9 ("First, a DMT symbol cannot be phase scrambled as that term is used in the claims by having its component QAM symbols rotated by the *same* amount."), 9 ("as interpreted in the FWD ('i.e., rotates by the same amount, the phase of a plurality of QAM symbols.')."). Our construction of "scrambling the phase

characteristics of the carrier signals" does not *require* rotating by the same amount. And as we applied the prior art, to the totality of the claim language, it is clear that we construed the totality of the claim language to require the phases of the carriers of the multi-carrier signal be rotated by varying amounts. For example, our Decision states

> Stopler further teaches that, "a phase scrambling sequence is applied to the output symbols," including "all symbols, not just the overhead symbols." *Id*. at 12:25–28. Patent Owner's expert, Dr. Short, agreed that Stopler is referring to phase scrambling QAM symbols. Reply 16–17 (citing Ex. 1027 (Tellado Dep.), 54:17–55:3, 55:19–24, 58:6–8, 59:9–12, 60:15–22). Stopler further teaches that a "scrambling sequence may be generated by a pseudorandom generator" that generates pairs whose sum "is used to select the amount of rotation to be applied to the symbol," singular; not "symbols" plural. Ex. 1012, 12:28–36. Thus, the most intuitive reading of Stopler supports Petitioner's contention that QAM Mapper and Phase Scrambler 82 determines an amount of rotation and rotates the phase of a single QAM symbol by that amount.

Dec. 26.

Patent Owner also objects to our characterization of Dr. Short's testimony as "admit[ing] that Stopler does not describe phase scrambling DMT symbols" (Dec. 25 (citing Ex. 1027, 60:11–14)). Req. Reh'g 9 (regarding Ex. 1027, 60:11–14). That testimony is as follows:

> Q. Well, you would agree with me that [Stopler] doesn't expressly teach applying the phase scrambler to the DMT as a whole?
>
> A. I would agree with that.

Ex. 1027, 60:11–14. We acknowledge that Dr. Short testified that he *understands* Stopler to be rotating all of the QAM symbols within a DMT symbol by the same amount, but the point made in our Decision

remains: Dr. Short clearly conceded, however, that Stopler does not *expressly teach* applying the phase scrambler to the DMT symbol as a whole. Dec. 25 (citing Ex. 1027, 60:11–14).

Patent Owner also argues that we misapprehended its argument that Stopler would adjust the phases of QAM symbols *over time* in order to reduce narrowband noise. Req. Reh'g 10 (citing PO Resp. 39 ("According to a second narrowband-noise-reducing technique, Stopler addresses narrowband noise at the frequency of an overhead pilot carrier by scrambling the phase of the pilot carrier over time from one DMT symbol to the next, *i.e.*, by ***inter***-symbol phase scrambling. *See* Ex. 2003 at ¶ 82."). As we noted in our Decision, however, Stopler teaches and Petitioner relies "not just on the scrambling of 'overhead signals, such as pilot tones,' (Pet. 13) but on the scrambling of *all* QAM symbols. Because neither Petitioner's argument nor Stopler's teaching of phase scrambling is limited to pilot tones, Patent Owner's argument is not persuasive." Dec. 27.

Patent Owner also argues that we misapprehended its burden by noting that "Patent Owner identifies nothing in Stopler to suggest that, in an alternative embodiment with a multicarrier modulator, QAM Mapper and Phase Scrambler 82 do not supply a plurality of phase-scrambled QAM symbols for modulation onto the plurality of carriers in the, e.g., DMT symbol." Req. Reh'g 11 (quoting Dec. 25–26). Petitioner has the burden of persuasion to prove unpatentability by a preponderance of the evidence. *See* 35 U.S.C. § 316(e); *Dynamic Drinkware, LLC v. Nat'l Graphics, Inc.*, 800 F.3d 1375, 1379 (Fed. Cir. 2015). For this element, we explained how Petitioner satisfied that burden based, *inter alia*, on express disclosure in Stopler. Dec. 26–27. The sentence to which Patent Owner objects merely

notes that, even assuming Stopler works as Patent Owner argues in an embodiment with a single-carrier modulator, that does not persuasively rebut the express disclosure upon which Petitioner relies. Accordingly, we are not persuaded that we misapprehended Patent Owner's burden.

Patent Owner also argues it was denied the opportunity to file a sur-reply. Req. Reh'g. 11–12. Patent Owner was, however, granted an opportunity to identify allegedly new arguments and evidence in Petitioner's Reply (Paper 25), and we considered the identified portions when reaching our Decision (Dec. 22 n.8). Although the "listing" format required Patent Owner to be efficient in its identification and required Petitioner to be efficient in its responsive paper, these papers provided "the information necessary to make a reasoned decision" (*Ultratec, Inc. v. CaptionCall, LLC*, 872 F.3d 1267, 1273 (Fed. Cir. 2017)) about whether the arguments and evidence raised in reply were outside the scope of a proper reply.

D. Shively's PAR

Finally, Patent Owner argues that we misapprehended or overlooked its argument that Shively's PAR would not be so "increased" or "high" that it resulted in clipping, as would be needed before a person of ordinary skill in the art had reason to modify Shively. Req. Reh'g 12–15. We addressed this argument and found it unpersuasive. Dec. 30–31. Mere disagreement with the Board's conclusion is not a proper basis for rehearing. It is not an abuse of discretion to have made a conclusion with which a party disagrees.

Moreover, Patent Owner alleges that "the FWD characterizes Shively as having a 'high' or 'increased' PAR." Req. Reh'g. 14 (citing Dec. 30). That is false. Our Decision states that it is undisputed that Shively's technique "will increase PAR" (Dec. 30–31), but does not characterize

Shively as having a "high" or "increased" PAR.[4] Our Decision relies upon page 28 of Patent Owner's Response (Paper 15), which concedes that "Shively's 'spreading' technique will contribute a small uptick in clipping probability." Patent Owner does not dispute, in its Request for Rehearing, Shively's technique *increases* PAR.

With respect to Patent Owner's argument that "there is no PAR *problem* presented by Shively" (Req. Reh'g. 14) and "the only PAR problem in this case relates to clipping" (*id.* at 15), we considered that argument and found it unpersuasive. Dec. 30–31. As we noted, "Petitioner's reason to combine does not depend on the PAR increase exceeding some specific numeric threshold," "there also is no dispute that equipment designed to handle a higher PAR can be larger, more expensive, and more power hungry than equipment designed to handle a lower PAR," and, therefore, "a person of ordinary skill in the art . . . would have been motivated to reduce PAR regardless of whether Shively's technique resulted in clipping." *Id*. In other words, as we explained in our Decision, Shively's PAR need not result in clipping in order to motivate a person of ordinary skill in the art because we are persuaded such a person would have been motivated sufficiently to reduce PAR by the benefit of being able to use smaller, less expensive, less power hungry components.

[4] In a sentence summarizing Petitioner's position, our Decision states, "*Petitioner alleges* that Shively's proposed system would have an 'increased' or 'high' PAR." Dec. 30 (quoting Pet. 14–15) (emphasis added). It should be obvious, however, that a summary of Petitioner's allegation is not a characterization by the panel.

IV. ORDER

Accordingly, it is ORDERED that Patent Owner's Request for Rehearing is *denied*.

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scrambler to randomize the data symbols would be to reduce the PAR of transmitted signals.

61. Stopler is analogous art to the '158 Patent because both Stopler and the '158 Patent are in the same field of endeavor (data communications and processing). Ex. 1012, 1:7-8; Ex. 1001, Abstract.

C. Reasons to Combine Shively and Stopler

62. It would have been obvious to a POSITA to combine Shively and Stopler because the combination is merely the use of a known technique to improve a similar device, method or product in the same way.

63. A POSITA would have recognized that by transmitting redundant data symbols on multiple carriers, Shively's transmitter would suffer from an increased peak-to-average power ratio. This increase is due to the fact that the overall transmitted signal in a multicarrier system is essentially the sum of its multiple subcarriers. When N subcarrier signals with the same phase and amplitude are added together, they have a peak power which is N times greater than their individual maximum powers.

64. Since Shively's subcarriers use quadrature amplitude modulation (QAM)—which encodes bits to be transmitted by modulating the phase and amplitude of the subcarrier—transmitting the same one or more bits on two different subcarriers causes those subcarriers to have the same phase and

dynamic range. To the extent that such components existed, they were expensive and highly inefficient. Less capable components would cause non-linear signal distortion, such as from amplitude clipping, resulting in data transmission errors. Since a high PAR brings numerous disadvantages, a POSITA would have sought out an approach to reduce the PAR of Shively's transmitter.

67. Stopler provides a solution for reducing the PAR of a multicarrier transmitter. Specifically, Stopler teaches that a bit scrambler followed by a phase scrambler can be employed to randomize the phase of the individual subcarriers. Ex. 1012, 12:24-28. A POSITA would have recognized that by randomizing the phase of each subcarrier, Stopler provides a technique that allows two or more subcarriers in Shively's system to transmit the same one or more bits, but without those two or more subcarriers having the same phase. Since the two subcarriers are out-of-phase with one another, the subcarriers will not add up coherently at the same time, and thus the peak-to-average power ratio for the overall system will be less than in Shively's original system.

68. Combining Stopler's phase scrambler into Shively's transmitter would have been a relatively simple and obvious solution to reduce Shively's PAR.

69. Market forces would have prompted the development of multicarrier communications devices, such as Digital Subscriber Line (DSL) modems, employing both redundant bit transmission and phase scrambling. As Shively

41. Dr. Short stated that in the 18,000 foot cable example he considered, less than half of the carriers are usable. Because less than half of the carriers can transmit data, Dr. Short stated that the transmitter transmitting a signal over an 18,000 foot cable operates at less than half average power. This is not the case for a 12,000 foot cable. The 12,000 foot cable does has very few (15) unusable carriers. Thus, most of the available carriers could be transmitting data on a 12,000 foot cable. Thus, the transmitter transmitting data on all carriers could operate at close to full average power. Because Shively's technique increases the frequency with which a large number of carriers will be aligned and create a spike in signal amplitude, Shively's technique significantly increases PAR. For a transmitter that was designed to transmit a *random* signal multicarrier signal, attempting to transmit a signal using Shively's bit-spreading technique will cause a significant increase in signal clipping.

VII. A simulation of a transmitter shows that Shively's technique increases PAR and the likelihood of clipping

42. Because Shively's technique transmits the same bits on multiple carriers, a POSITA would have intuitively known that Shively's technique would significantly increase the likelihood of carriers' phases aligning, and therefore increase PAR.

43. A POSITA would also have known that quantifying the exact level of increase in PAR could not be calculated using a simple Gaussian approximation.

Instead, quantifying the increase in PAR would have called for running numerical simulations of a transmitter. Such simulations were commonly created and run by engineers in the 1990s to investigate the impact of proposed modulation techniques on a communication system's performance. A POSITA would have known how to create and run a simulation of Shively's bit-spreading technique. In order to quantify the increase in PAR, I designed and wrote a simulation of an ADSL transmitter that calculates the clipping probability of a DMT symbol for different values of PAR under different simulation conditions.

44. Exhibit 1034, provided with this declaration, is a true and accurate copy of the code for the simulation that I wrote, which runs in MathWorks Matlab or GNU Octave.

45. My simulation takes into account different scenarios that can occur when data is transmitted in an ADSL system. Equations #1 and #2 show the likelihood that all carriers will phase-align perfectly and generate a spike in power in a system that has *n* carriers. However, spikes can also occur when various carriers are only partially phase-aligned. Furthermore, the amplitude of a spike will depend in part on the specific frequencies of the carriers that are phase-aligned. Shively describes replicating data (a *k*-bit symbol) over adjacent carriers. Ex. 1011, 11:16-19.

I. INTRODUCTION

Pursuant to 37 C.F.R. § 42.71(d), TQ Delta, LLC ("Patent Owner") requests rehearing of the Panel's final written decision ("FWD"), Paper 41. The FWD is based on an overbroad construction of "scrambling the phase characteristics of the carrier signals" that misapprehends or overlooks the specification of the '243 patent, Patent Owner's discussion, and the statements of Petitioners, including their own expert. Furthermore, given a proper construction of "scrambling the phase characteristics of the carrier signals," the FWD misapprehends or overlooks that Stopler's[2] alleged phase scrambling is different than what is claimed. The FWD also mistakenly concludes, based on a misapprehension of the record, that one of skill in the art would have (1) considered Shively's[3] PAR without the frame of reference of its clipping rate and (2) considered Shively to have a "high" or "increased" PAR. But the relative terms "high" or "increased" PAR lack meaning without a frame of reference.

II. THE PANEL'S CONSTRUCTION OF "SCRAMBL[E/ING]…A PLURALITY OF CARRIER PHASES" IS OVERBROAD

Patent Owner asserted that this term (and the similar term "scramble … a plurality of phases") should be construed to mean "adjusting the phases of a

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[2] U.S. Patent No. 6,625,219 B1; issued Sept. 23, 2003 (Ex. 1012) ("Stopler").

[3] U.S. Patent No. 6,144,696 B1; issued Nov. 9, 2000 (Ex. 1011) ("Shively").

plurality of carriers in a single multicarrier symbol by pseudo-randomly varying amounts." POR, Paper 12 at 14. Petitioners, on the other hand, argued that it needs no construction, "since [Stopler] uses the same 'phase scrambling' terminology to describe pseudo-random phase changes." Reply, Paper 20 at 7.

The FWD, however, diverged from both of these approaches and construed the term to mean "adjusting the phases of a plurality of carriers in a single multicarrier symbol." FWD, Paper 41 at 9. But this cannot be a proper construction of this term because it leaves open the possibility that all of the phases within a single multicarrier symbol are adjusted by a single (*i.e.*, same) amount. The FWD misapprehends or overlooks that, under any proper construction, there must at a minimum be *varying amounts* by which the phases are adjusted within a single multicarrier symbol (*i.e.*, *from carrier-to-carrier*) such that PAR is reduced. Under the construction set forth in the FWD, the claim term would still be met where the phases of a plurality of carriers in a single multicarrier signal are adjusted even if each of the phases of the plurality of carriers in the single multicarrier symbol are adjusted by the same amount. Such uniform adjustment, however, would not result in the recited "scrambling" where phase adjustment varies among carriers—and therefore would not reduce PAR.

A. There Is Universal Agreement That Scrambling Phases As Claimed Reduces PAR

As both Patent Owner and Petitioners explained, the claimed "scrambling" must lower PAR. Patent Owner's discussion on this point is clear, unrefuted, and fully supported by the '243 patent. *See, e.g.*, POR, Paper 12 at 16 ("As the '243 patent explains, PAR in the transmission signal is reduced by adjusting the carrier phases within a single DMT symbol. *See* [Ex. 1001] at 6:30–53. If the carrier phases were only adjusted from one symbol to the next, PAR would not be reduced. *See* Ex. 2003 at ¶¶ 41–42."); Ex. 2003 (Short Decl.) at ¶ 42; Ex. 1001 at 6:30–53.

Petitioners' arguments showed that they agree that the claims required adjusting phase***s*** of the individual carrier***s***. For example, Petitioners alleged:

> A POSITA would have known that one way to reduce PAR is to scramble phases of individual carriers.

Reply, Paper 17 at 12.[4] Another example is Petitioners' section heading: "IV. Stopler's phase scrambler reduces PAR because it scrambles phases of individual QAM symbols." Reply, Paper 17 at 16.

[4] Patent Owner disagrees and contests Petitioners' conclusions and untimely submission of evidence, but agrees that the claimed phase-scrambling must reduce

Even the FWD acknowledges that the claimed phase scrambling reduces PAR.[5] *See* FWD, Paper 41 at 25 ("The known technique is identified as phase scrambling. Pet. 14–15 (citing Ex. 1009, 27–28). The similar device is Shively's modem. Pet. 16. And the improvement to it is the same as in Stopler—to reduce PAR. Pet. 15 (citing Ex. 1009, 28–29)."); *id.* at 29 ("In addition, Dr. Tellado testified that a person having ordinary skill in the art would have recognized that the purpose of Stopler's phase scrambler to randomize data symbols would be to reduce PAR of transmitted signals…."); *id.* at 31 ("Accordingly, a drive to reduce equipment costs would have motivated a person having ordinary skill in the art to include Stopler's phase scrambler into Shively's transmitter to reduce PAR.").

Thus, all parties and the Panel are in agreement that phase scrambling reduces PAR. And, of course, if PAR is not reduced, then there can be no phase scrambling.

PAR.

[5] Patent Owner does not agree with the conclusions of the FWD, but notes only that PAR reduction using phase scrambling is discussed and not refuted.

B. The FWD's Construction Includes Situations in Which PAR Is Not Reduced

The construction in the FWD of "scrambl[e/ing]…a plurality of carrier phases" (and the similar term "scramble … a plurality of phases") is overbroad because it includes scenarios in which PAR is not reduced. For example, if all of the carriers in a single multicarrier symbol are rotated by the same amount, then PAR would not be reduced. That is because the phases would not be "scrambled" in any sense. Instead, when undesirably aligned carrier phases in a single multicarrier symbol are rotated by the same amount, they will still align by the same undesirable amount. The FWD overlooks or misapprehends that, without phase *variance* from carrier-to-carrier within a single multicarrier symbol, there can be no reduction in PAR according to the claims and the invention of the '243 patent, and therefore no phase scrambling as claimed. *See*, *e.g.*, Petition, Paper 2 at 14, and Ex. 1009 (Tellado Decl.) at ¶ 64 ("Having phase-aligned subcarriers causes a high peak-to-average power ratio (PAR), since all of the subcarriers add up coherently at the same time."); POR, Paper 15 at 49 ("[O]ut of all the evidence in this *inter partes* review, only the inventor of the '243 patent recognized the problem of high PAR due to phase-aligned carriers."); Reply, Paper 20 at 20 ("Such non-random, structured data increases the likelihood for phases of carriers to align, thereby increasing PAR. CSCO-1009, ¶60.").

United States Court of Appeals
for the Federal Circuit

TQ Delta, LLC v. Cisco Systems, Inc., 2018-1766, -1767

CERTIFICATE OF SERVICE

I, Melissa Pickett, being duly sworn according to law and being over the age of 18, upon my oath depose and say that:

Counsel Press was retained by MCANDREWS, HELD & MALLOY, LTD., counsel for Appellant to print this document. I am an employee of Counsel Press.

On **November 21, 2018** counsel has authorized me to electronically file the foregoing **JOINT APPENDIX** with the Clerk of Court using the CM/ECF System, which will serve via e-mail notice of such filing to all counsel registered as CM/ECF users, including the following principal counsel for the other parties:

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Courtesy paper copies will also be mailed to the above principal counsel at the time paper copies are sent to the Court.

Six paper copies will be filed with the Court within the time provided in the Court's rules.

November 21, 2018

/s/ Melissa Pickett
Counsel Press